Mineral Development Division
Department of Mines and Energy
Government of Newfoundland and Labrador

CURRENT RESEARCH

Report 84-1

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PREFACE

This publication is the eleventh in the Mineral Development Division's annual Report of Activities series.

In 1983, the Division continued the two-year cooperative geoscientific program begun in 1982 with the Federal Department of Energy, Mines and Resources. Geological mapping, mineral deposit studies, and geochemical surveys carried out under that program are identified in this report. Some of these projects were funded by the Geological Survey of Canada, and led by GSC personnel. We thank the Geological Survey of Canada for permission to include reports on these projects in this publication.

In addition to its contribution to the cooperative program, the Division carried out geological mapping in northern Labrador, geochemical and Quaternary mapping in the Strange Lake area, and aggregate resource assessment throughout the Province. A new provisional geological map of the island of Newfoundland was produced, and work continued on computerization of geoscientific data, on the core storage program, and on the mineral occurrences inventory system.

The Canada-Newfoundland cooperative minerals program ends on March 31, 1984. Negotiations are underway to provide continued cooperative Federal-Provincial support for the geoscientific program. These negotiations will hopefully result in an expanded program in the 1984 field season.

B.A. Greene, Director
Mineral Development Division

Any reader who would like to write a rebuttal to, or discussion of, any report contained in this volume is invited to submit it to the editor by November 1, 1984, to be considered for inclusion in Report 85-1.

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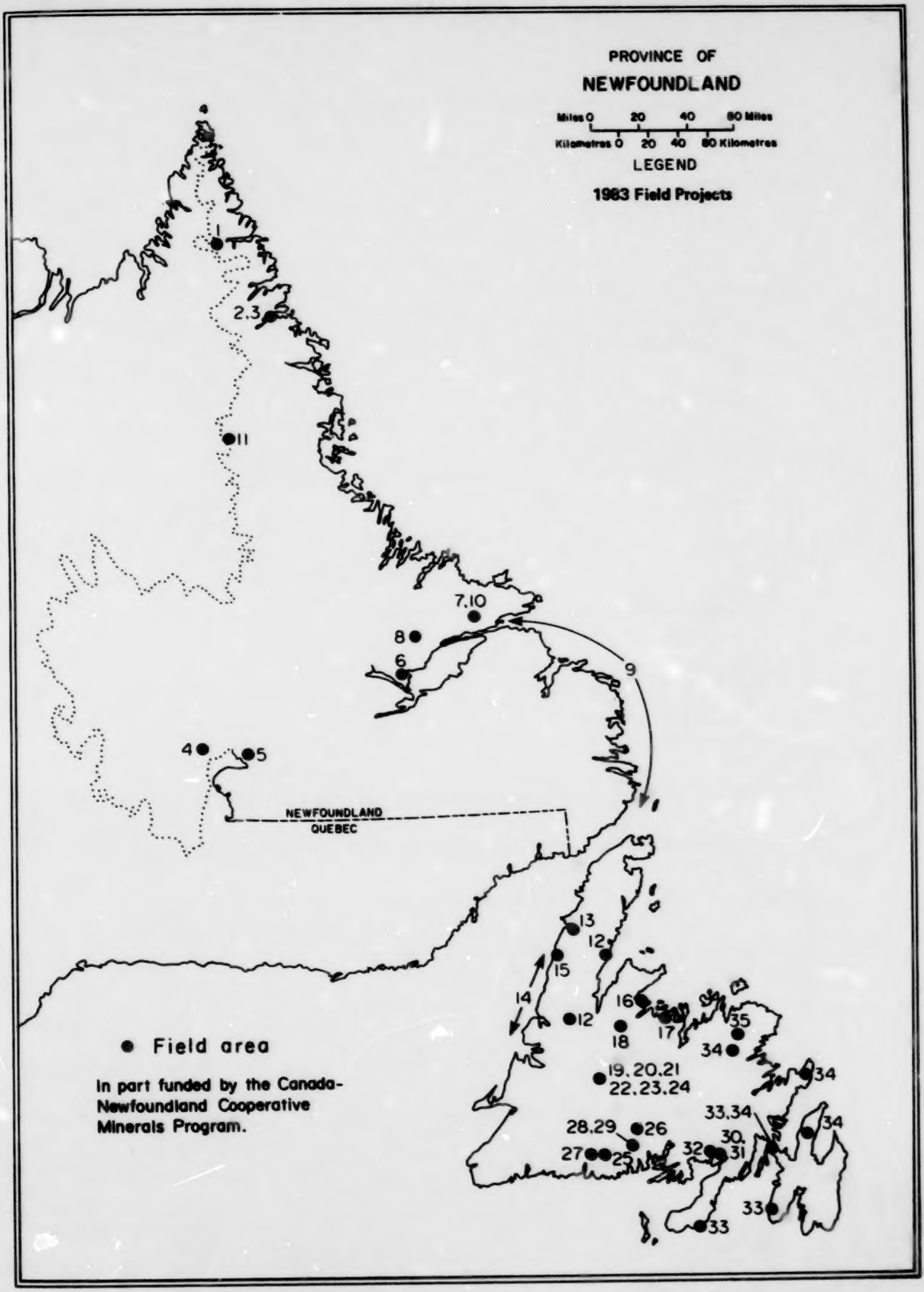
PROVINCE OF
NEWFOUNDLAND
Miles 0 20 40 60 Miles
Kilometres 0 20 40 60 Kilometres
LEGEND
1983 Field Projects
● Field area
In part funded by the Canada-Newfoundland Cooperative Minerals Program.
NEWFOUNDLAND
QUEBEC
1
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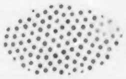
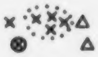
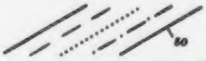
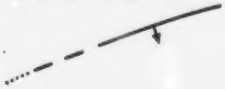
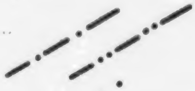
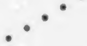
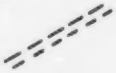
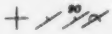
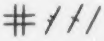
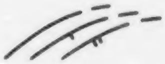
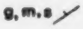
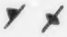
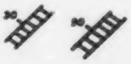
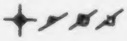
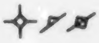
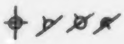
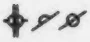
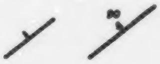
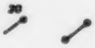
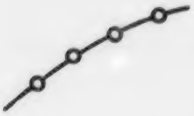
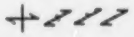
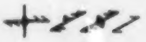
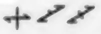
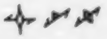
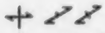
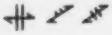
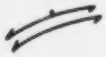
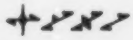
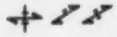
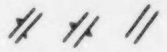
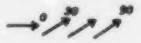
LIST OF SYMBOLS USED ON GEOLOGICAL MAPS AND FIGURES

Drift covered area	
Rock outcrop, area of outcrop, probable outcrop, float, frost-heaved rock	
Geological boundary (defined, approximate, assumed, gradational, dip indicated)	
Intrusive contact with younger unit indicated	
Unconformity (defined, assumed)	
Limit of geological mapping	
Limit of area surveyed with aircraft	
Bedding, tops known (horizontal, inclined, vertical, overturned)	
Bedding, tops unknown (horizontal, inclined, vertical, dip unknown)	
Bedding, general trend (dip unknown, top unknown; dip and top known; dip known, top unknown)	
Bedding, estimated dip (gentle, moderate, steep)	
Igneous flow banding (inclined, vertical)	
Igneous intrusive sheets (inclined, vertical)	
Primary igneous layering, tops known (horizontal, inclined, vertical, overturned)	
Primary igneous layering, tops unknown (horizontal, inclined, vertical)	
Strike and dip of pillows, tops known (horizontal, inclined, vertical, overturned)	
Strike and dip of pillows, tops unknown (horizontal, inclined, vertical)	
Primary igneous mineral lamination (inclined, vertical)	
Primary igneous mineral lineation (inclined, vertical)	

Flow Contact	
Zone containing xenoliths	△
Zone of intrusive agmatite	▲
Roof pendant (unit number indicated; too small to map separately)	△
Zone containing autoliths	▽
Breccia of various origins	▼
Slaty cleavage (horizontal, inclined, vertical, dip unknown)	
Strain-slip cleavage (horizontal, inclined, vertical, dip unknown)	
Schistosity, cleavage, foliation; used where ages of foliation are indicated on the map (horizontal, inclined, vertical)	
Schistosity of unknown age	
S_1	
S_2	
Schistosity, gneissosity, cleavage, foliation, general trend	
Gneissic foliation (horizontal, inclined, vertical, dip unknown)	
Gneissic banding (horizontal, inclined, vertical)	
Axial plane of minor fold (inclined, vertical, dip unknown)	
Lineation (horizontal, inclined, inclined but plunge unknown, vertical)	
Type of lineation denoted by letter:	
Mineral lineation	M→
S intersections	S→
Microcrenulations	C→
Boudin axes	B→
Deformed clasts	D→
Igneous inclusions	I→
Rodding, mullion structure	R→
Metamorphic aggregates	A→
Deformed pillows	P→

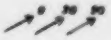
Age of lineation and of minor fold axes

Lineation of unknown age

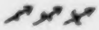
L_1

L_2

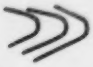
Axes of minor folds (horizontal, inclined, vertical)



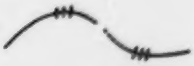
Sense of vergence of minor structures (used with minor fold axes symbol or lineation S intersection symbol; read looking along the arrow)



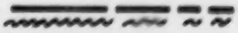
Structural trend (from aerial photographs)



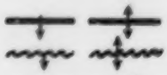
Lineament (from aerial photographs)



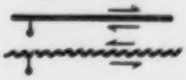
Fault (defined, approximate, assumed)



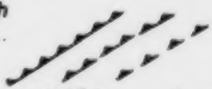
Fault (inclined, vertical)



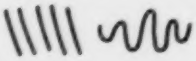
Fault (solid circle indicates downthrown side, arrows indicate relative movement)



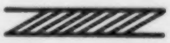
Thrust fault (teeth in direction of dip; defined, approximate, assumed) (teeth indicate upthrust side)



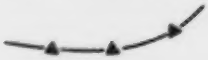
Zone of numerous imbricate thrust faults



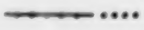
Fault zone, shear zone (width indicated)



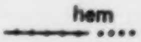
Tectonic slide



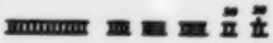
Vein fault (defined, assumed)



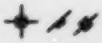
Mineralized bed or seam (hematite)



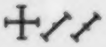
Dike, vein, or stockwork (defined, approximate, assumed; unit number and dip indicated)



Joint (horizontal, inclined, vertical)



Sheeted dikes (horizontal, inclined, vertical)



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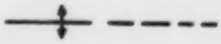
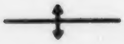
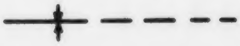
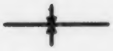
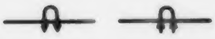
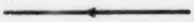
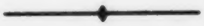
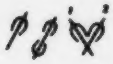
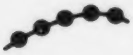
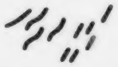
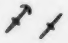
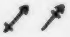
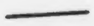
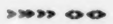
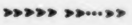
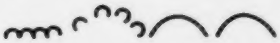
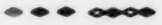
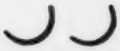
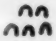
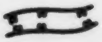
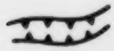
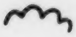
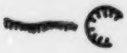
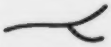
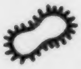
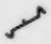
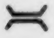
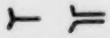
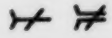
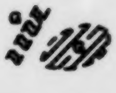


Antiform	
Syncline (defined, approximate, assumed)	
Synform	
Anticline and syncline (overturned)	
Anticline or syncline (arrow indicates plunge)	
Antiform or synform	
Glacial striae (direction of ice movement known, unknown). Numbers indicate relative age, 1 being the oldest	
End moraine	
Minor moraines, rib moraines, washboard moraines, "annual" moraines, till ridges transverse to ice flow (irregular, straight)	
Drumlins, drumlinoid ridges (direction of ice movement known, unknown)	
Crag and tail hills and ramps	
Glacial linear feature	
Pingo or palsen	
Esker (direction of flow known, unknown)	
Esker (continuous, discontinuous)	
Raised beaches	
Limit of marine or lacustrine submergence (well marked, assumed)	
Dunes	
Area of sand dunes	
Buried valley	

Abandoned river channel, spillway, ice-marginal channels, rill patterns, etc.	
Landslide scar	
Escarpment and cirques	
Fossil locality	Ⓕ
Locality where age has been determined, in millions of years	Ⓐ 180
Ice divide	— — —
Land system boundary	
Location of measured section	
Gravel pit or quarry (active, abandoned)	× ×̲
Borrow pit (active, abandoned)	×̄ ×̲̄
Rock dump or tailings	
Rock quarry (active, abandoned)	⚒̲
Mine (lead, zinc)	⚒ Pb, Zn
Mine (lead, zine; abandoned)	⚒̲ Pb, Zn
Mineral prospect; mineral occurrence (manganese)	×9 × Mn
Placer deposit (gold)	× Au
Show of oil and gas (abandoned)	✸
Show of gas(abandoned)	✲
Gas producer	○
Oil producer	✹
Oil and gas producer	●

Location of drilling	○
Dry (abandoned)	
Water source or disposal	
Shearing and dip	
Salt spring	ss○-
Hot spring	hs ○-
Mineral isograd	-■-■-■-■-■-
Other alternatives when more than one	-□- -○- -◆- △ ★
Shaft, raise, winze	■ ■ ▣
Shaft (abandoned)	▣
Trench	
Open cut; axial	
Adit or tunnel	
Adit or tunnel (caved)	
Borehole	●BH ●BH 3
Diamond drill hole	● DDH
(Surface projection of geology inferred)	—○
Sinkhole	○ SH
Gossan	G 
Trace of coal seam	—— ——

ADDITIONAL SYMBOLS

Geological boundary (geophysically defined)	
Geophysical conductor	
Roche moutonnee	
Meltwater channel	
Sinkhole	**SH**
Open pit, mine or quarry	
Locality where age has been determined, in thousands of years before the present	Ⓕ$^{12.5}$
Till fabric (direction known, unknown, known plus cross fabric)	

SAMPLE LOCALITIES (SURFICIAL)

Glacial till	●	*Clay*	+
Gravel	●	*Organic*	✱
Sand	○	*Rock*	Ⓡ
Silt	■	*Pleistocene fossil*	Ⓕ

NAIN - CHURCHILL PROVINCE CROSS-SECTION; RIVIERE BAUDANCOURT - NACHVAK LAKE

by

R.J. Wardle
Labrador Mapping Section

Abstract

This paper reports on the western transect of a project designed to provide a cross-section of the Nain-Churchill Province boundary. The eastern transect was completed in 1982.

The predominant rock type in the transect area is a tonalite-granodiorite gneiss, largely at amphibolite facies, but locally preserving relict granulite facies assemblages. The gneiss contains numerous mafic enclaves, including metagabbro and anorthosite, and may be broadly compared, although not directly correlated, with the Nachvak gneiss of the eastern transect. Also present within the granodiorite-tonalite gneiss are bands of supracrustal gneiss dominated by garnetiferous psammitic gneiss, but also including rusty sillimanite-bearing pelitic gneiss, quartzite, marble and ultramafic rocks. These bear close resemblance to the Archean Upernavik supracrustals of the Nain Province.

The eastern end of the transect is underlain by an extensive unit of mylonitic, garnet-rich tonalite gneiss (Tasiuyak gneiss) interpreted to have developed by massive melting and wholesale injection of leucogranite (sensu lato) *into Archean, Upernavik-type supracrustals.*

The extreme western end of the transect is underlain by psammitic-pelitic gneisses which appear structurally younger than adjacent units and which are confirmed as belonging to the lower Proterozoic Lake Harbour Group.

The western transect lies entirely within the inner Churchill Province and was strongly reworked and metamorphosed, probably at upper amphibolite facies conditions during the Hudsonian orogeny. Structures formed during this event are largely west verging, east dipping and steepen towards the eastern end of the transect.

The overall structural picture produced by combination of western and eastern transects is of a structural fan centered on the Tasiuyak gneiss. The fan may have developed either in response to upward ramping of a major east directed intracrustal thrust fault or in response to collision of two crustal blocks. The Tasiuyak gneiss appears to represent the deepest levels of Archean crust which have been exposed in the core of the fan.

A prominent subhorizontal quartz lineation is associated with mylonitic fabrics in the axial part of the fan and is probably related to syn- or post-thrust, strike-slip faulting and associated lateral shearing.

Introduction

Work this year completed the field component of a two year project on the boundary of the Nain and Churchill structural provinces, begun in 1982 in the Nachvak Fiord area (Figure 1).

The project has now provided a 100 km long cross-section across this poorly known structural boundary. The cross-section can be conveniently divided into: an eastern transect, which is the area completed in 1982 (Wardle, 1983) in the Nachvak Fiord area; and a western transect which is the area reported on here.

The results of the 1982 eastern transect may be summarized as follows.

The Nain-Churchill boundary was found to be a broad zone within which Archean crust of the Nain Province was progressively reworked during the Hudsonian Orogeny circa 1.8 Ga. The boundary area was divided, from east to west, into three structural zones: the Nain Province, Churchill Border (or Foreland) Zone and Churchill Inner Zone.

The Nain Province was found to consist of Archean crust for which the following history was recognized:

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[1] Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X5

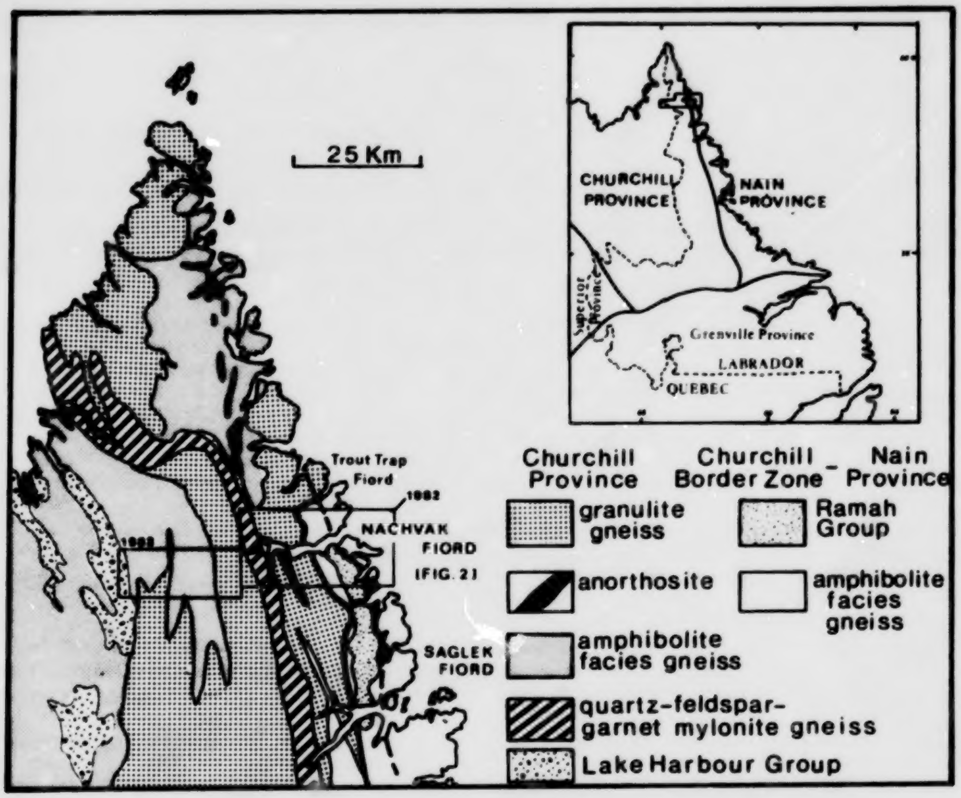

25 Km
Trout Trap Fiord
1982
NACHVAK FIORD (FIG. 2)
1983
SAGLEK FIORD
CHURCHILL PROVINCE
NAIN PROVINCE
Superior Province
Grenville Province
LABRADOR
QUEBEC
Churchill Province
Churchill Border Zone
Nain Province
granulite gneiss
anorthosite
amphibolite facies gneiss
quartz-feldspar-garnet mylonite gneiss
Lake Harbour Group
Ramah Group
amphibolite facies gneiss

Figure 1: *Regional geological setting of project area in northern Labrador.*

1. formation of early mafic gneisses, locally associated with supracrustal gneisses;
2. widespread intrusion of granitoid plutons incorporating early mafic gneisses as inclusions;
3. regional deformation, migmatization and granulite grade metamorphism of those plutons circa 2.8 Ga resulting in formation of Nachvak gneiss;
4. intrusion of Kammarsuit granite circa 2.7 Ga;
5. zonal mylonitization and retrogression circa 2.6 to 2.5 Ga;
6. intrusion of regional post-tectonic mafic dike swarm circa 2.4 Ga.

The predominant rock type in the Nain Province is the Nachvak gneiss which was subjected to static amphibolite-greenschist facies retrogression during late Archean and Hudsonian metamorphic events.

The Churchill Border, or Foreland, Zone is underlain predominantly by the granitoid Nachvak gneiss but also contains lower Proterozoic sediments of the Ramah Group deformed in the Hudsonian Orogeny. Hudsonian deformation in the gneiss is restricted to zonal reworking in shear zones which change in character from brittle fracture zones in the east to ductile shear zones in the west. The border zone also contains a granulite facies - amphibolite/greenschist facies retrograde isograd, previously thought to be the Nain-Churchill boundary, which marks the western limit of combined Late Archean - Hudsonian retrograde alteration. Structural style is that of vertical tectonics and easterly directed overthrusting.

The Churchill Inner Zone contains a westerly extension of the Nachvak gneiss which encloses a linear belt of Archean anorthosite. Nachvak gneiss is bounded to the west by a major belt of quartz + feldspar + garnet mylonitic gneiss (Tasiuyak gneiss) of enigmatic origin. Hudsonian straightening and mylonitic fabrics are pervasive in the inner zone and the late 2.4 Ga dikes have been transposed into the regional fabric. Both western Nachvak and Tasiuyak gneiss were intensely mylonitized in what was thought to be a major transcurrent shear zone.

The geology of the eastern transect is summarized in the tectonostratigraphic chart (Figure 2) and cross-section (Figure 3).

The geology of the western transect was previously known only from the regional reconnaissance mapping of Taylor (1979). In general the transect area was proposed to be underlain by granitoid gneisses, differentiated into amphibolite and granulite facies map units (Figure 1), and migmatitic paragneisses. The paragneisses were divided into biotite-quartz-feldspar paragneisses

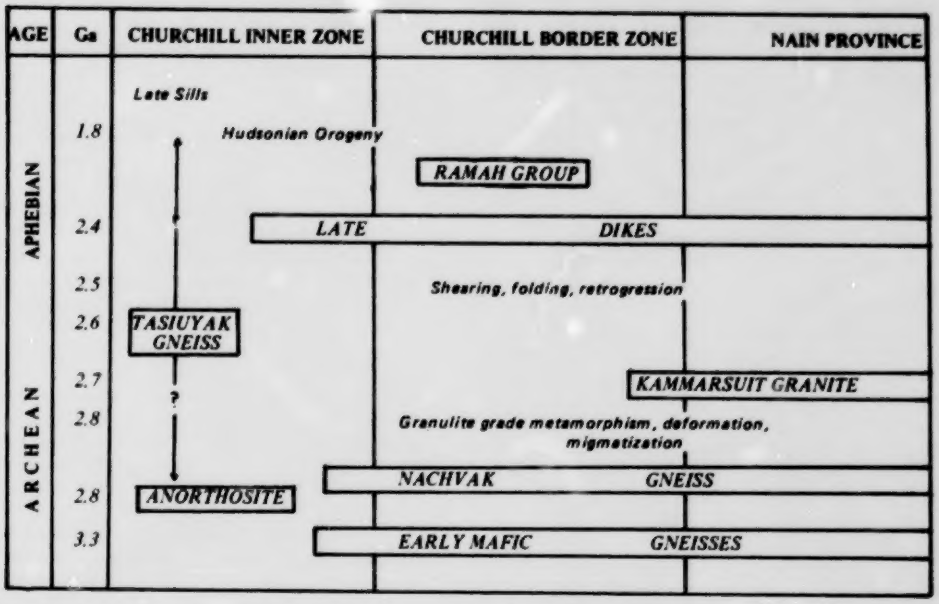

AGE
Ga
CHURCHILL INNER ZONE
CHURCHILL BORDER ZONE
NAIN PROVINCE
APHEBIAN
ARCHEAN
1.8
2.4
2.5
2.6
2.7
2.8
2.8
3.3
Late Sills
Hudsonian Orogeny
RAMAH GROUP
LATE DIKES
Shearing, folding, retrogression
TASIUYAK GNEISS
?
KAMMARSUIT GRANITE
Granulite grade metamorphism, deformation, migmatization
NACHVAK GNEISS
ANORTHOSITE
EARLY MAFIC GNEISSES

Figure 2: *Tectonostratigraphic summary of geology of eastern transect area (after Wardle, 1983).*

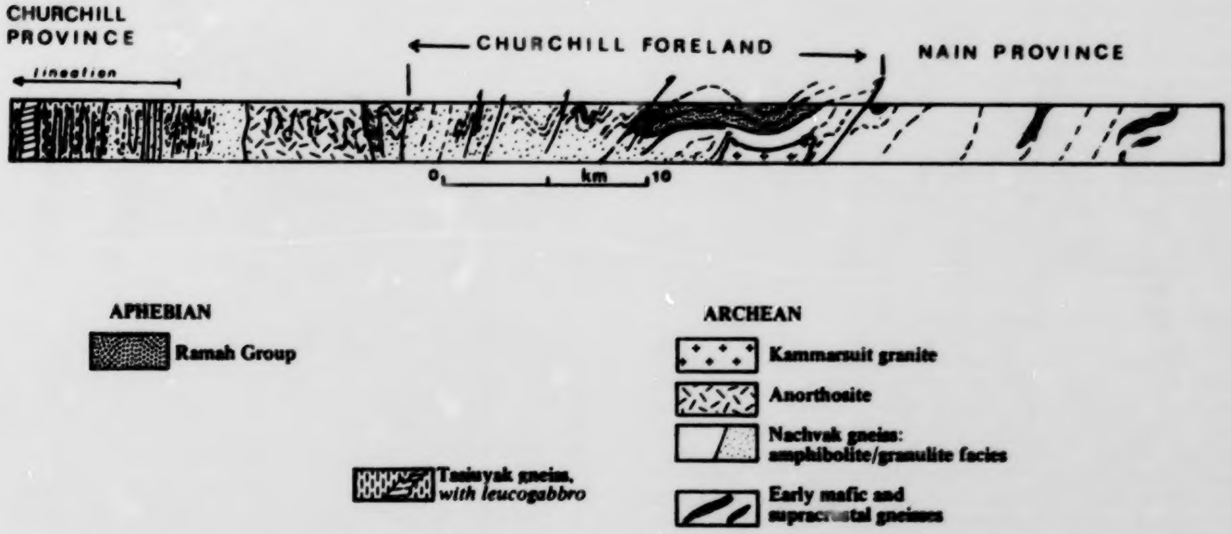

CHURCHILL PROVINCE
lineation
CHURCHILL FORELAND
NAIN PROVINCE
0
km
10
APHEBIAN
Ramah Group
Tasiuyak gneiss, with leucogabbro
ARCHEAN
Kammarsuit granite
Anorthosite
Nachvak gneiss: amphibolite/granulite facies
Early mafic and supracrustal gneisses

Figure 3: *Cross-section of eastern transect (after Wardle, 1983).*

(ALpg - Taylor, 1979) and rusty graphite-bearing paragneisses (ALrc), both of which were assigned to the lower Proterozoic Lake Harbour Group (Jackson and Taylor, 1972; Taylor, 1979). For reasons discussed below, only the rusty gneisses are now included within the Lake Harbour Group as shown in Figure 1.

The western and eastern transects are conveniently divided by the important and regionally extensive unit of quartz + feldspar + garnet mylonite gneiss (Afg - Taylor, 1979) which was recognized by Taylor *(op. cit.)* as a fundamental feature of the eastern Churchill Province (Figure 1) and which was later referred to as the Tasiuyak gneiss by Wardle (1983).

Field work in the western transect was accomplished largely by a series of ground traverses following the river system which flows from the Quebec-Labrador border, near the west flowing Riviére Baudancourt (Figure 4), east to Nachvak Lake. The area around Nachvak Lake, which lies in the heart of the Torngat Mountains (relief 0.5 to 2 km) and is not easily covered on foot, was completed by helicopter mapping. However, this work was hampered by bad weather with the result that ground coverage in the Nachvak Lake area is not as complete as elsewhere in the transect.

The geology of the western transect is shown in Figure 4 which has been modified from the regional maps of Taylor (1979).

Geology

The transect area is predominantly underlain by granitoid gneisses (Unit 1) which are interbanded with a variety of migmatitic supracrustal gneisses (Unit 2). In the east these were strongly migmatized and injected by leucotonalite-granite and were subsequently intensely mylonitized (Unit 3). A younger series of supracrustal gneisses, belonging to the Lake Harbour Group, is differentiated in the western part of the transect (Unit 4) and is the only unit for which a lower Proterozoic age is reasonably assured.

Granitoid Gneisses (Unit 1)

These are generally gray gneisses of overall tonalitic composition, although pink granitic varieties are locally present. They are strongly migmatitic and often well banded with a stromatic migmatite texture. The gneisses in the western half of the transect show the association biotite + hornblende ± garnet and also contain biotite clots, probably pseudomorphs after pyroxene. Orthopyroxene is increasingly more prevalent along the eastern part of the transect where the granitoid gneisses alternate between gray, predominantly hornblende-bearing rocks, and buff granulite facies gneisses. It was not possible to substantiate the manner in which Taylor (1979) divided the area into amphibolite and granulite facies map units. The western part of the area (generally that part west of the dashed line marking the limit of lineation development on Figure 4) is largely at amphibolite facies, whereas the eastern part of this area consists of a mixture of amphibolite and granulite facies assemblages.

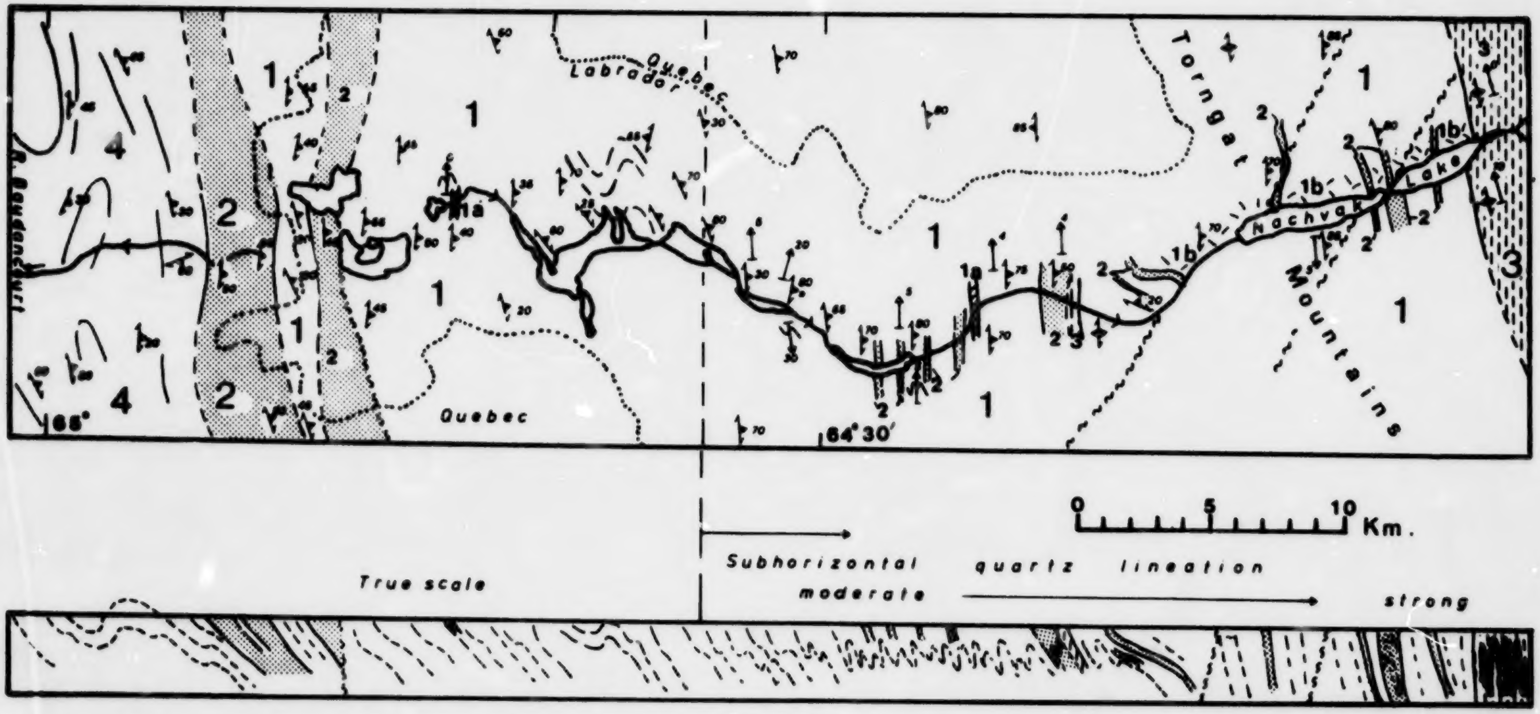
The granitoid gneisses are also characterized by numerous zones of elongate amphibolite and amphibolite gneiss inclusions which may occur either in thin trains or as extensive zones tens of metres wide. The inclusions appear to have been derived by intense migmatization, injection and tectonic disruption of amphibolite layers within the granitoid gneisses. Their protolith is generally unrecognizable; however, some of the zones contain leucogabbroic-anorthositic compositions (1a) which were probably derived from layered mafic bodies either intruded into the granitoid gneiss protolith, or incorporated as inclusions within it.

In the area around Nachvak Lake the migmatitic granitoid gneisses give way to massive, buff weathering granodiorite to tonalite gneisses (1b) which, whilst strongly foliated and lineated, lack the complex textures and structures typical of the gneisses to the west. These gneisses contain abundant fresh orthopyroxene and are clearly at granulite facies. They also contain abundant inclusions of amphibolite - mafic granulite and lesser ones of leucogabbro - anorthosite gneiss. The nature of the contact between these massive granulite gneisses and the remainder of the Unit 1 granitoid gneisses has not been observed, largely due to the extremely rugged nature of the Nachvak Lake area. Pending examination of this contact it appears likely that the massive gneisses are structurally younger than the bulk of the tonalite gneisses and may represent pre- to synkinematic intrusive sheets.

Supracrustal Gneisses (Unit 2)

These were recognized by Taylor (1979; his unit ALpg) although their confirmed extent is considerably less than indicated by his reconnaissance mapping.

They occur as numerous bands, varying in width from less than a metre to 3 km, and are interspersed within the granitoid gneisses. The most extensive bands occur in the west where they consist largely of


R. Baudancourt
65°
64°30'
Quebec
Labrador
Torngat Mountains
Nachvak Lake
0 5 10 Km.
True scale
Subhorizontal quartz lineation
moderate
strong

APHEBIAN

4 **Lake Harbour Group.** *Pelitic to psammitic gneisses.*

ARCHEAN (?)

3 *Mylonitic interbanded garnet leucogranite and garnet metasedimentary gneisses.* Tasiuak gneiss

2 **Supracrustal gneisses** *including: garnet psammite and rusty sillimanite gneiss, with minor quartzite marble and ultramafic rocks.*

1 **Granitoid gneisses.** *Largely migmatitic tonalite to granodiorite gneisses with abundant amphibolite inclusions. Largely retrogressed granulite grade rocks.*

1a - *metagabbroic to anorthositic gneisses.*

1b - *massive foliated to lineated buff, granulite grade tonalite.*

Figure 4: *Geology of the western transect between Rivière Baudancourt and Nachvak Lake. Geology in part modified from Taylor, 1979.*

garnet-rich quartz + feldspar + biotite psammitic gneiss, with thin interbands of rusty sillimanite + biotite pelitic gneiss and rare bands and pods of ultramafic rocks. Garnet in these rocks typically has a mauve color. These gneisses are generally strongly migmatitic with a white, quartz-rich, leucotonalite-granodiorite-granite leucosome component, in many cases of pegmatitic character.

In the central part of the transect the supracrustal gneisses form much narrower bands, the width of which is locally exaggerated in Figure 4. These bands again consist largely of garnetiferous psammitic gneiss but are also associated with impure, garnetiferous gray quartzite, rusty sillimanite + biotite + graphite gneiss, pods of gray marble and calc-silicate, and ultramafics and amphibolite - mafic granulite. These gneisses are also strongly migmatitic with a white leucotonalite-leucogranite leucosome; in the eastern part of the transect they are overprinted by mylonitic fabrics and resemble the Tasiuyak gneiss (Unit 3) described below.

Supracrustal gneisses are well exposed as prominent rusty bands on the fiord walls around Nachvak Lake, but are generally difficult to reach. Where examined they consist of mylonitic, garnetiferous gneisses which in most respects are transitional between the clearly recognizable supracrustal gneisses to the west and the Tasiuyak gneiss.

Contact relationships of supracrustal gneiss and granitoid gneiss are generally obscured by intense migmatization and pegmatite sheeting which seems concentrated in contact regions. Premetamorphic relationships of the supracrustal and granitoid gneisses are, therefore, unknown.

Tasiuyak Gneiss (Unit 3) - *mylonitic, interbanded garnet leucotonalite-leucogranite and garnet metasedimentary gneiss*

This unit, which divides the eastern and western transects, was examined mainly during the 1982 field season and found to consist of a monotonous, homogeneous, leucocratic quartz + plagioclase + garnet gneiss. On washed surfaces the gneiss is highly distinctive, being finely banded with mauve garnet-rich bands alternating on a 2 to 10 cm scale with white, quartz + plagioclase leucocratic bands containing 1 to 3 cm garnet porphyroblasts. The garnet-rich bands also contain biotite, sillimanite and locally graphite. On weathered surfaces the gneiss is a rusty brown color and fine structures are obscured. Staining of polished slabs shows the gneiss to comprise a fine centimetric scale alternation of leucogranitic and leucotonalitic compositions. The garnet-rich bands are generally of granitic composition.

The central part of the unit also contains a pretectonic leucogabbroic body (Wardle, 1983).

The eastern part of the unit is dominated by an intense mylonitic fabric. However, in the central and western parts of the unit this fabric is less intense and is locally seen to be discordant to an isoclinally folded compositional banding.

The most relevant observations from this season's work come not from the main body of the Tasiuyak gneiss but from the previously described belts of supracrustal gneiss (Unit 2). As described above, these consist predominantly of migmatitic garnet-bearing psammitic gneiss. The leucosome veins vary from centimetres to metres in width, from microgranite to pegmatite in texture, and are generally subparallel to foliation. In composition they range from leucogranite to leucotonalite and contain 10 to 30% mauve garnet porphyroblasts. Where these rocks have been strongly straightened and mylonitized, as for example in the band located 7.5 km west of Nachvak Lake, the result is a banded, mylonitic gneiss composed of alternating mauve garnet + biotite + sillimanite bands and garnet leucotonalite-leucogranite bands, which is in most respects identical to the main body of Tasiuyak gneiss.

It is proposed, therefore, that the Tasiuyak gneiss is a two-component gneiss in which the dark purple fraction represents relict (restite) supracrustal material, and the pale gray to white fraction the migmatitic leucotonalitic-leucogranite material. Leucogranite *(sensu lato)* forms a much larger component of the Tasiuyak gneiss (60 to 70 percent) than in the Unit 2 supracrustal gneisses and this is taken to indicate that the metasedimentary protolith of Unit 3 was subject to either massive melting or wholesale injection of leucogranite *(sensu lato)*, probably during granulite facies metamorphism.

The present homogeneous, finely banded character of the gneiss was imposed during mylonitization and tends to obscure the earlier and more significant compositional variation within the unit. •

Pelitic-psammitic gneiss - Lake Harbour Group (Unit 4)

The western end of the transect is underlain by a sequence of metasedimentary gneisses initially recognized by Taylor (1979; his unit ALrc) and assigned to the Lake Harbour Group.

During the past season's work these gneisses were examined only within the valley of the tributary flowing west into Riviere Baudancourt. They consist of well banded (3 to 20 cm), rusty weathering pelitic to psammitic gneisses. The pelitic gneisses are biotite-rich and also bear sillimanite. The psammitic ones are usually gray quartz + feldspar + garnet gneisses varying to gray, impure quartzite. Locally the gneisses display a rhythmic alternation of pelitic and psammitic bands suggestive of derivation from a bedded, shale-sandstone sequence.

The pelitic-psammitic gneisses are in general much less migmatitic than the adjacent supracrustal gneisses of Unit 2 and have a very different field appearance. In particular their red garnet contrasts with the mauve garnet of Unit 2. The pelitic-psammitic gneisses are also generally much rustier and have more clearly defined air-photo structural trends than adjacent units.

The contact of the pelitic-psammitic gneisses and the supracrustal gneisses of Unit 2 is unexposed in the transect section. However, the pelitic-psammitic gneisses become more quartz-rich towards the contact and contain bands of coarse feldspathic quartzite, possibly derived from granule conglomerate. It is strongly suspected, therefore, that the contact is a tectonized unconformity.

Structure and Metamorphism

The overall structural style of the western transect is illustrated in cross-section in Figure 4.

Structural style in the western half of this section is dominated by gentle east dipping gneissic fabrics refolded into west verging F_2 folds. These folds are seen as both minor outcrop scale structures and major map scale features.

In the central part of the cross-section the overall attitude of gneissic foliation steepens, and F_2 folds become more prevalent and assume a tight to isoclinal style. F_2 folding is also associated with the development of S_2 transposition fabrics, east dipping ductile shear zones, and a shallow, north plunging quartz lineation. The lineation is apparently colinear with F_2 fold hinges, although coincidence of the two structures can be reliably demonstrated in relatively few outcrops.

The eastern part of the cross-section is dominated by a vertical to steep, east dipping gneissosity which is largely a composite fabric produced by transposition of early gneissic and migmatitic banding with the S_2 fabric. There is no discernible megascopic folding; however, the supracrustal gneisses contain abundant, minor, isoclinal folds. Steep, east dipping, ductile shear zones are present throughout this part of the transect but are concentrated within the supracrustal units, and in particular the Tasiuyak gneiss which marks the most pronounced development of mylonitization in the area. Development of a strong subhorizontal quartz lineation is associated with ductile shear and mylonite zones.

The granitoid gneisses, particularly the massive granulite facies tonalite gneisses (subunit 1b), are relatively free of ductile shear fabrics; however, they do possess the same strong, subhorizontal quartz lineations as the other units.

Metamorphic assemblages in the western part of the transect area are predominantly of the upper amphibolite facies, as indicated by sillimanite-bearing assemblages in the supracrustal rocks of Units 2 and 4. However, the presence of probable biotite pseudomorphs of pyroxene within the granitoid gneisses of Unit 1 indicates the early attainment of granulite facies conditions in that unit.

The amphibolite facies alteration varies from static replacement of granulite assemblages to dynamic recrystallization within shear zones and is correlated with the period of F_2 folding and ductile shearing.

Granulite facies assemblages become increasingly prevalent in the eastern half of the transect area and are characterized by the general paragenesis: quartz + feldspar + biotite + orthopyroxene + hornblende ± clinopyroxene. Pyroxene, in particular orthopyroxene, is clearly unstable with respect to hornblende and is an early metamorphic phase.

Orthopyroxene has been observed at only one locality within the metasedimentary gneisses of Unit 2. However, mafic bands within the metasedimentary gneisses record the assemblage: plagioclase + orthopyroxene + clinopyroxene (minor) + biotite indicating ambient granulite grade conditions. Development of orthopyroxene within the metasedimentary gneisses may have been suppressed by relatively high internal $P\,H_2O$, high $f\,O_2$, or unsuitable composition.

Relatively pristine granulite facies assemblages are prevalent in the Nachvak Lake area, at the eastern end of the transect. The granulite facies mineralogy in this area has been cataclastically deformed within shear zones but has suffered relatively little hydrous alteration, a feature which was also noted in adjacent parts of the eastern transect (Wardle, 1983).

Age and Correlation of Units

In the preceding description little mention has been made of the age of the various lithological units. Taylor (1979) inferred all rocks in the transect region to be of Aphebian age; in particular, the supracrustal rocks were all assigned to the Lower Proterozoic Lake Harbour Group. There is, however, little isotopic age support for this inference; available data is restricted to scattered K-Ar mineral ages which fall mostly in the 1.6 to 1.7 Ga range (Taylor, 1979) and are presumably related to uplift and cooling.

The granitoid gneisses show clear evidence of a complex and prolonged crustal evolution. The most important events in this history appear to have been an early widespread granulite facies metamorphism, of unknown age, and an amphibolite facies reworking associated with F_2 folding and ductile shearing. This latter event is presumed to have been the Hudsonian Orogeny. The granitoid gneisses are broadly comparable with the Nachvak gneiss of the eastern transect, in terms of both overall composition and their abundance of mafic to anorthositic inclusions (Wardle, 1983). The Nachvak gneiss underwent a granulite event circa 2.8 Ga, which is the typical timing of granulite metamorphism in the North Atlantic craton (Bridgwater et al., 1978), and was zonally retrogressed and reworked in the Hudsonian. It is accordingly strongly suspected, although not proven, that the granitoid gneisses of the western transect are broadly time-equivalent to the Nachvak gneiss, and underwent a similar Archean granulite event which produced pervasive migmatization. Some support is given to this interpretation by a K-Ar hornblende age of 2050 Ma on granulite gneiss 15 km south of Nachvak Lake (Taylor, 1979). This age is too old for the Hudsonian and may reflect partial resetting of an Archean age. Additional support is also given by Rb-Sr determinations from granulites of the northeastern Churchill Province of Labrador in general (Taylor, 1978), which have yielded mixed isochrons with both Archean (2.64 Ga) and Hudsonian (1.86 Ga) components. Anantha Iyer (1980) demonstrated close chemical and petrographic similarities between granulite grade rocks of the interior Churchill Province and those of the Nain Province, south of the transect area.

A major uncertainty remains concerning the age of the massive granulites (1b) around Nachvak Lake. These obviously have a very fresh stable granulite mineralogy, and there is some uncertainty as to whether this is a relict Archean assemblage which has been reworked under anhydrous conditions in the Hudsonian, or it is a prograde Hudsonian assemblage. The former interpretation was favored by Wardle (1983) for granulite gneisses immediately east of the Tasiuyak gneiss; however, the issue remains open pending isotopic dating.

The supracrustal rocks of the western transect are divided here into two units, the pelitic-psammitic gneisses (Unit 4) and the garnetiferous psammitic gneisses (Unit 2).

The garnet psammitic gneisses of Unit 2 bear very close similarities to the Archean Upernavik Supracrustals (3.3 to 2.8 Ga) of the Nain Province. These have been extensively described by Bridgwater et al. (1975) and Ryan et al. (1983; 1984) from the Saglek Fiord area (Figure 1), and consist predominantly of mauve-garnet-rich psammitic gneisses, rusty sillimanite-bearing pelitic gneisses, impure quartzite and minor marble and calc-silicates, together with variable amounts of ultramafic, and amphibolite - mafic granulite. The latter units are thought to have been derived from mixed high level mafic intrusions and mafic volcanic sequences.

The Upernavik supracrustals are also intimately interbanded with surrounding granitoid gneisses on a scale varying from metres to kilometres. The only major difference between the supracrustals of the Saglek area and the western transect is that in the Saglek area the supracrustals commonly contain much larger proportions of mafic material.

At present it is impossible to assign unequivocally an Archean age to the supracrustal rocks of Unit 2; however, on the basis of lithologic and structural similarity they bear more resemblance to the Upernavik supracrustals than to any of the known lower Proterozoic sequences in the interior Churchill Province.

The supracrustal protolith for the Tasiuyak gneiss (Unit 3) is also proposed to have been an Upernavik-type, Archean supracrustal sequence which was subject to massive melting and leucogranite *(sensu lato)* leucosome formation in what was probably the 2.8 Ga granulite event, although in the absence of isotopic age data a Hudsonian age cannot be ruled out.

The pelitic-psammitic gneisses of Unit 4 (Lake Harbour Group) appear to be structurally younger than the adjacent Archean (?) gneisses, and an early Proterozoic age is highly probable. The Lake Harbour Group is a major component of the interior Churchill Province and consists of a thick, clearly differentiated sequence of marble, rusty pelitic gneiss, quartzite and amphibolite which is reasonably established as being of Lower Proterozoic age (Jackson and Taylor, 1972). The group may be broadly equivalent to the Ramah Group of the eastern transect area.

Discussion

Comparisons between the western and eastern transects are of critical importance to the understanding of the tectonic evolution of the Nain-Churchill boundary region in the area of the established cross-section.

The granitoid gneisses of the western transect bear overall resemblance to the circa 2.8 Ga Nachvak gneiss. Both are of similar composition and contain abundant zones of mafic inclusions, locally recognizable as metagabbroic bodies, including meta-anorthosite. However, there are also major differences. The most obvious difference, and one which would be expected, is that the gneisses of the western transect have been much more pervasively reworked during the Hudsonian Orogeny. However, much of the migmatization and granulite grade metamorphism is believed to be an inherited Archean effect. A second and more fundamental difference is that the Archean(?) supracrustal rocks of the western transect bear little resemblance to those present within the Nachvak gneiss of the eastern transect. Supracrustal associations in the Nachvak gneiss are dominated by the mafic gneisses described above, probably derived from igneous intrusions, and similar in many respects to the mafic component of the Upernavik supracrustals (Wardle, 1983). However, metasedimentary material is rare and is limited to thin bands of garnetiferous quartzite or metachert. In contrast the supracrustals of the western transect are more extensive and are dominated by metasedimentary material. Thus, whilst the Archean(?) gneisses of the western transect may be broadly time-equivalent to those in the east, they cannot be directly correlated.

There are also important differences in Hudsonian structural style between the two transects which are summarized in the cross-sections of Figures 3 and 4. The western transect is dominated by west verging structures whereas the eastern transect contains mainly east verging folds and associated thrusts. When put together the two transects form an overall fan structure, the core of which is formed by the Tasiuyak gneiss with its generally vertical structures.

The east verging structures are clearly related to overthrusting onto the Nain Province craton. This is a well known and expected feature of the Churchill Foreland Zone. What is less clear is the significance of the west verging structures. These are not obviously related to overthrusting but the structural style would suggest that this is to be expected. Also the structures (F_2 folds and ductile shear zones) are clearly second generation ones, even in the Lake Harbour Group, and indicate only late Hudsonian tectonic style. The regional geological maps of the northern Churchill Province (Taylor, 1979) in the transect region indicate that shallow, east dipping foliations are widespread and that westerly structural vergence may be a regionally important feature of this part of the interior Churchill Province.

A detailed discussion of models for the tectonic evolution of the Nain-Churchill boundary is beyond the scope of this paper. However, some provisional ideas are proposed which will be more fully considered in a future publication.

The development of structural fans is not an unusual feature of foreland fold and thrust belts, and is usually related to thrusting and in particular the development of thrust ramps. Deformation over the thrust ramp produces progressive folding and imbrication which may eventually lock the thrust and then produce back thrusting and back folding. This may be viewed as a single stage process (e.g. Price et al., 1981 - Porcupine Creek Fan) or a multistage process (e.g. Brown and Read, 1983 - Shuswap terrane). Following this model the Nain-Churchill boundary fan might be interpreted to have developed over a major intracrustal thrust ramp. The most likely locus for this would be the eastern contact of the Tasiuyak gneiss, although this contact was severely modified during later lateral shearing. The scale of the Nain-Churchill fan, however, is very large and would likely have to be related to a ramp of major crustal proportions.

An alternative model for production of large scale fans is collision of crustal blocks (e.g. Price, 1981 - Kootenay Arc; Coward, 1983 - western Himalayas). In this interpretation it is conceivable that the western half of the fan represents a crustal block which collided against the Nain craton producing both easterly and westerly directed thrust structures.

In either model the core of the fan is likely to be occupied by the rocks of deepest crustal level, in this case the Tasiuyak gneiss. All the features of this gneiss are commensurate with deep crustal evolution; however, the most significant part of this evolution, the massive melting and leucogranite *(sensu lato)* formation, appears to have occurred in the Archean and to have simply been exhumed in the Hudsonian.

The structural picture is also complicated by the presence of a strong subhorizontal lineation associated with mylonitization and folding in the central and west-central parts of the fan. This implies a subhorizontal, north-south trending attitude for the principal axis of the finite strain ellipsoid and obviously indicates a lateral shear rather than an overthrust regime. Field evidence indicates colinearity of F_2 fold hinges and the lineation, suggesting a coeval relationship. It is also conceivable that the lineation is superimposed, although if this is the case it is surprising that there is no record of an earlier, east plunging lineation more obviously related to fold and thrust development.

Regardless of the problems of timing of lineation development, it is apparent that the axial regions of the fan were modified by lateral shear, either during or subsequent to folding and thrusting. The most likely cause of the lateral shear would be a major strike-slip fault zone located along the fan axis.

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THE ARCHEAN - PROTEROZOIC BOUNDARY
IN NORTHERN LABRADOR, REPORT 2

by

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Abstract

The Nain and Churchill structural provinces and the boundary between them have been investigated in the Hebron Fiord area of northern Labrador. The Nain Province comprises migmatized early Archean orthogneiss and interleaved supracrustal gneiss belts intruded by several generations of late Archean tonalite to granite. Diabase dikes intrude all lithologies. Metamorphism of the gneisses and some of the granites reflects granulite facies conditions. The Churchill Province comprises predominantly garnetiferous tonalitic gneisses with lesser mafic and ultramafic granulites, and hypersthene-bearing quartzo-feldspathic gneisses, the latter in part derived from Proterozoic reworking of the adjacent Archean complex. Ramah Group supracrustals in the eastern Churchill Province are metamorphosed to amphibolite facies and are structurally interleaved with Hudsonian-refoliated Archean basement. The Archean-Proterozoic boundary is defined by a 2 to 5 km zone in which rocks of the Nain Province are progressively modified by Hudsonian thermo-tectonism upon approaching a sharply faulted boundary with high grade gneisses of the Churchill Province. No minerals of economic importance were detected in the area.

INTRODUCTION

The 1983 season was the second of a two-year program to investigate the nature of the boundary between the Archean Nain Province and the Proterozoic Churchill Province, and to assess the mineral potential of northern Labrador between Saglek and Hebron Fiords. The 1982 season concentrated on the Saglek Fiord section of the zone (Ryan et al., 1983); during the 1983 season most of the field work was carried out in the Hebron Fiord area. Heavy Arctic pack-ice along the Northern Labrador coast delayed positioning of helicopter fuel and prevented small-boat work on the coast; hence mapping did not commence until July 28, 1983. Two 1:50,000 map sheets (14L/2,3; Figure 1) were mapped during the field season which ended on September 1. Ryan, Martineau and Lee were responsible for regional mapping of the Archean terrane covered by 14L/2; Korstgaard concentrated on the Churchill Province and its boundary with the Archean complex on 14L/3. Much of the area included in Figure 2 was ground-traversed, but helicopter reconnaissance was also employed, especially to complete coverage of the northwest corner and the southern one-third of 14L/3.

Studies complementary to the regional mapping program were also conducted during the 1983 season. Some of these are a continuation of investigations begun last year, but new programs were also initiated. D. Bridgwater and L. Schiotte (Geologisk Museum, Copenhagen, Denmark) have been concentrating on geochronological studies of the early Archean Uivak gneisses and their migmatization in the northern coastal stretch. A. Nutman (Grønlands Geologiske Undersøgelse, Copenhagen, Denmark) conducted detailed studies of the various lithologies that make up the Nulliak assemblage, a series of pre- 3.6 Ga supracrustal rocks occurring as rafts in the Uivak gneisses. F. Mengel (Memorial University, St. John's, Newfoundland) has begun a comprehensive mapping and stratigraphic/metamorphic/structural analysis of the southern extension of the Ramah Group, an Aphebian supracrustal belt in the eastern part of the Churchill Orogen. K.

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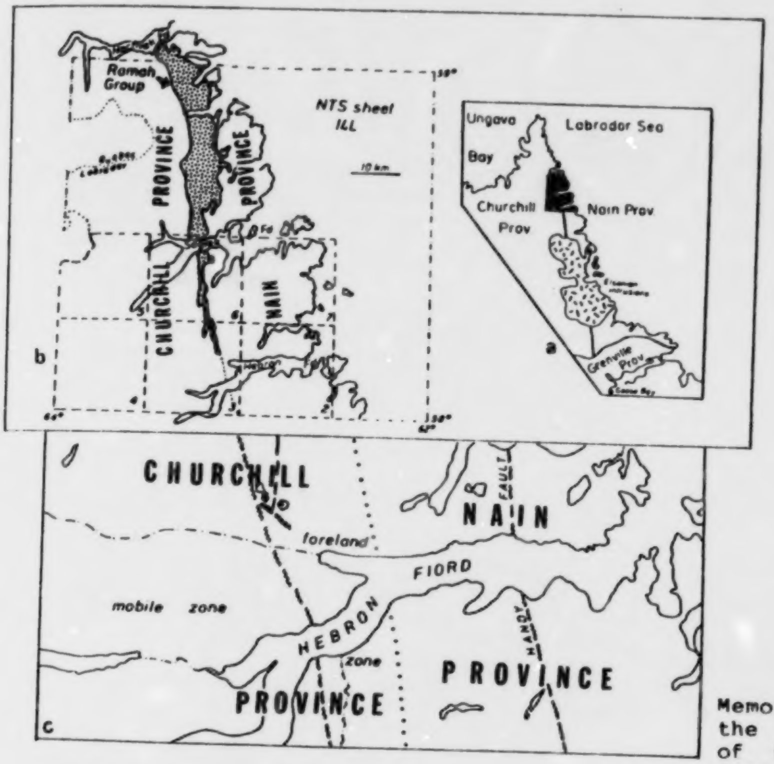

Figure 1. *Index maps to study area. (a) Shaded area is part of northern Labrador covered by NTS grid 14/L. Major lithotectonic elements of Labrador are after Greene (1972). (b) Outline of 1:50,000 sheet areas at southwest corner of 14L. Sheets 14L/2, 3 were mapped in 1983. (c) Structural subdivisions of the study area. Dotted line represents easternmost limit of Hudsonian deformed diabase dykes in the Archean terrane, and thus defines the eastern boundary of the Churchill Province foreland zone. See text for details.*

Collerson (Australian National University, Canberra) collected material for isotopic investigations of both the Archean and Proterozoic crustal blocks.

Geological Setting and Previous Work

The study area presents a cross-section of the junction between the Archean Nain Province (Taylor, 1971) and the early Proterozoic Churchill Province (Figure 1). The Nain Province is the western portion of the fragmented North Atlantic Craton (Bridgwater et al., 1973) and contains gneisses older than 3.6 Ga (Hurst et al., 1975; Collerson, 1983); the latest major deformation probably occurred circa 2.7 Ga. The Churchill Province in the study area is part of the southeast projection of an extensive, irregularly shaped Proterozoic orogen which stretches westward and northward into central and Arctic Canada (Davidson, 1972). The Churchill Province comprises rocks which exhibit a strong structural and metamorphic imprint from the Hudsonian Orogeny circa 1.8 Ga, but the majority of the rocks of this younger mobile belt in the study area are probably derived from Archean protoliths.

The major geological elements in northern Labrador were outlined and discussed by Taylor (1969, 1970, 1971, 1979). Joint work by the G.S.C. and Memorial University in 1974 and 1975 led to the unravelling of the geological history of the Archean complex in the eastern Saglek fiord area and the coastal segment directly north of the present study area, *cf.* Bridgwater et al. (1975), Bridgwater and Collerson (1976), Collerson et al. (1976), and Collerson and Bridgwater (1979). As part of the 1975 Memorial University program, the senior author conducted a study of the eastern half of the peninsula bounded by Iterungnek and Hebron Fiords (Ryan, 1977). In addition Barton (1975) and Collerson, Brooks et al. (1982) presented discussions of some aspects of the geochronology of the Archean gneisses from the Hebron area. The Churchill Province in this area, however, has received little attention, and apart from Taylor's regional reconnaissance studies, no information is available.

Definition of Archean and Proterozoic Tectonic Elements

The definition of Archean vs. Proterozoic structural elements is relatively straight forward in general terms in the Nain and Churchill Provinces of Northern Labrador as outlined by Taylor (1971, 1979). However, as Morgan (1975a) correctly pointed out, Hudsonian effects extend beyond the Churchill Province mobile zone into the terrane immediately to the east. This is dramatically illustrated by the thermotectonism which affected the Aphebian Ramah Group, and Morgan therefore assigned the Ramah Group to the Churchill Province.

Although he did not define its extent, he recognized that the Hudsonian imprint was also evident in the Archean gneisses east of the Ramah Group and assigned them to the "Hudsonian foreland" zone (Morgan, 1975b, 1978). This designation was also used by Ryan et al. (1983) who noted that where Ramah Group was not present, the late Archean diabase dike swarm could be used to indicate the eastward extent of Hudsonian deformation into the Nain Province. The delineation of Hudsonian effects on the Archean terrane becomes more problematical when these two critical markers are absent. Such is the case for parts of the boundary zone in the Hebron Fiord area. However we have been able to show that the Hudsonian overprint extends up to 6 km into the Nain Province east of the Churchill Province mobile zone (see below) and we include this area in the foreland zone of the Churchill Orogen (Figure 1c).

Nain Province

The Archean complex of the Nain Province of northern Labrador has been subdivided into several stratigraphic units of orthogneiss and paragneiss as a result of work in the Saglek area in the mid-1970's (*cf.* Bridgwater et al.,1975; Collerson et al., 1976; Bridgwater and Collerson, 1976; Bridgwater et al., 1978; Collerson et al., 1981). These lithologic and chronologic studies have shown that the geological history of the Nain Province (Table 1) entails a complex sequence of deposition, igneous activity, metamorphism and deformation. The major aspects of the geology of the Saglek area follow, summarized briefly.

The early Archean (pre-3.4 Ga) Uivak gneisses are the oldest regionally distributed gneisses. These comprise a tonalitic to granodioritic suite (Uivak I) which is intruded by and structurally interleaved with a more potassic, Fe-rich augen gneiss (Uivak II). Both subgroups contain rafts of older supracrustal rocks (banded iron formation, quartzite, calcareous metasediment, and mafic to ultramafic compositions) termed the Nulliak assemblage, and it can be demonstrated that both the Nulliak assemblage and the Uivak I gneisses had suffered polyphase deformation prior to emplacement of the Uivak II protolith. All the above lithologies were intruded by a suite of massive to feldspar megacrystic basic dikes (Saglek dikes) circa 3.2 to 3.4 Ga ago. Interleaved with the early Archean orthogneisses is a varied group of rocks termed the Upernavik supracrustals comprising pelitic, psammitic and calcareous metasedimentary rocks and basic rocks which are interpreted to be of both extrusive and intrusive origin. No Saglek dikes have been observed in the Upernavik supracrustals, and they are interpreted as either an original cover sequence developed on the Uivak gneisses or else an exotic assemblage tectonically juxtaposed against the Uivak gneisses. The intercalation of Uivak gneisses and Upernavik supracrustals probably occurred in the period between 3.2 and 2.8 Ga. Contacts between the two groups are usually marked by podiform ultramafic bodies.

Table 1: *Simplified geological history of the Nain Province in northern Labrador. Includes data from Collerson (1983).*

Emplacement of diabase dike swarm	(2.3-2.4 Ga)
Emplacement of Igukshuak granite	(2.5 Ga)
Emplacement of late synkinematic to post kinematic Saglek sheets and Ikarut tonalite	(2.7-2.8 Ga)
Emplacement of synkinematic granites	(2.8 Ga)
Reworking of Uivak gneisses to give Kiyuktok gneisses and Iterungnek gneisses, granulite facies metamorphism	(2.8 Ga)
Intercalation of Upernavik supracrustals and Uivak gneisses	
Deposition of Upernavik supracrustals	
Intrusion of Saglek dykes	(3.2-3.4 Ga)
Deformation and metamorphism	
Intrusion of protoliths for Uivak II gneisses	(circa 3.4 Ga?)
Deformation and metamorphism	
Intrusion of protoliths of Uivak I gneisses	(circa 3.8 Ga)
Deposition of Nulliak assemblage	(pre-3.8 Ga)

The whole Archean complex was subjected to a period of major crustal reconstitution circa 2.8 Ga. This is manifested in the development of granulite facies assemblages and reworking of the Uivak gneisses to produce a series of migmatites which were termed the Kiyuktok gneisses in the Saglek Fiord area west of the Handy Fault (Kerr, 1980) and the Iterungnek gneisses in the Hebron Fiord area east of the Handy Fault (Ryan, 1977). Equivalent migmatites at amphibolite facies east of

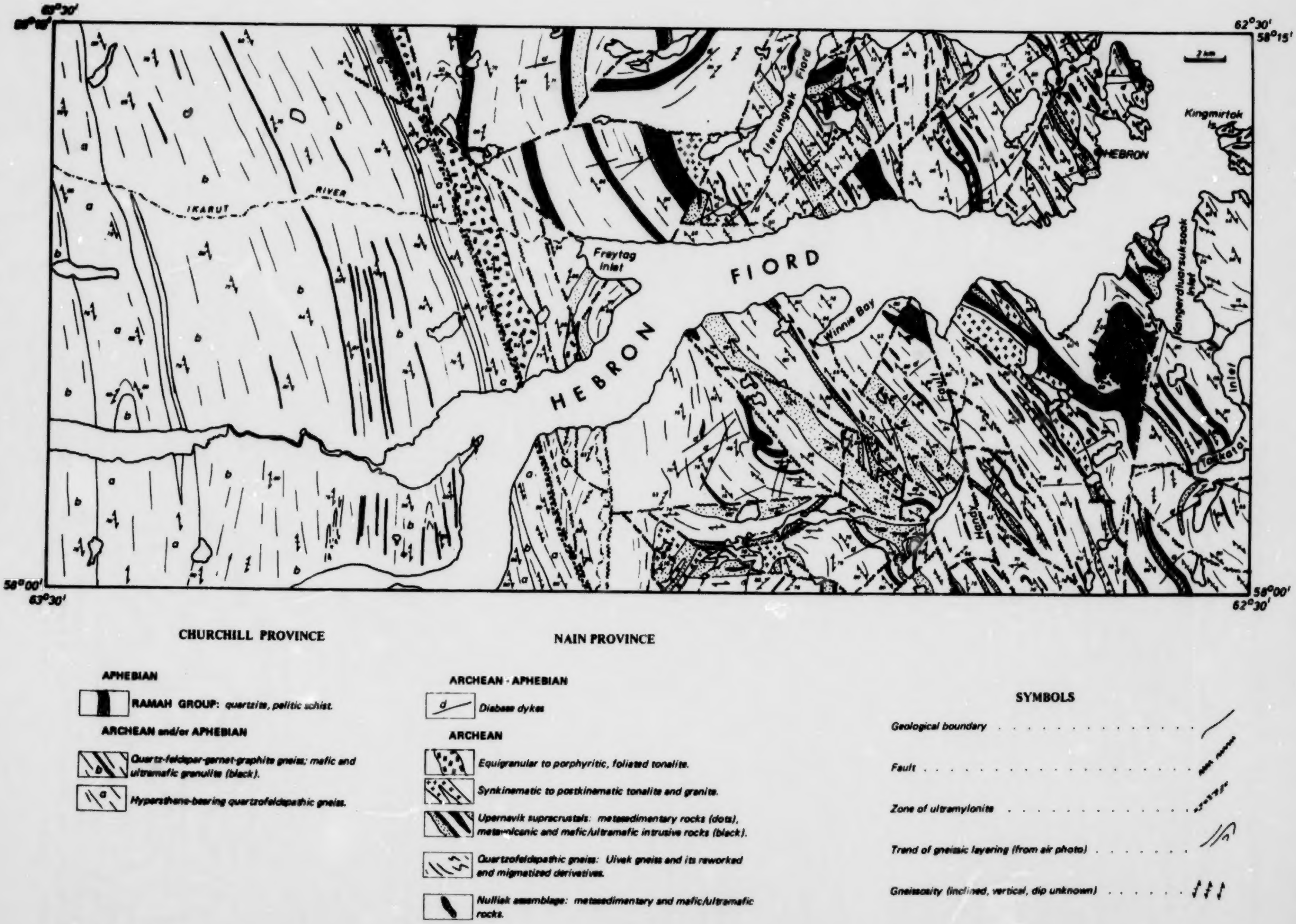
63°30'
58°15'
62°30'
58°15'
2 km
Kingmirtok Is.
HEBRON
Iterungnek Fiord
IKARUT RIVER
Freytag Inlet
HEBRON FIORD
Winnie Bay
Fault
Handy
Kangerdluarsuksoak Inlet
Inlet
Tasiuyak
58°00'
63°30'
58°00'
62°30'
a
b
d
CHURCHILL PROVINCE
APHEBIAN
RAMAH GROUP: quartzite, pelitic schist.
ARCHEAN and/or APHEBIAN
Quartz-feldspar-garnet-graphite gneiss; mafic and ultramafic granulite (black).
Hypersthene-bearing quartzofeldspathic gneiss.
NAIN PROVINCE
ARCHEAN - APHEBIAN
Diabase dykes
ARCHEAN
Equigranular to porphyritic, foliated tonalite.
Synkinematic to postkinematic tonalite and granite.
Upernavik supracrustals: metasedimentary rocks (dots), metavolcanic and mafic/ultramafic intrusive rocks (black).
Quartzofeldspathic gneiss: Uivak gneiss and its reworked and migmatized derivatives.
Nulliak assemblage: metasedimentary and mafic/ultramafic rocks.
SYMBOLS
Geological boundary
Fault
Zone of ultramylonite
Trend of gneissic layering (from air photo)
Gneissosity (inclined, vertical, dip unknown)

Figure 2. Geological sketch map of the Hebron Fiord area.

the Handy Fault at Saglek were termed "undifferentiated gneisses" by Hurst et al. (1975). This 2.8 Ga event was also accompanied by the emplacement of syntectonic garnet- and orthopyroxene- bearing granites and pegmatites. Intruded late synkinematically with the reworking of the Uivak gneisses were the Ikarut gneiss protolith and the Saglek tonalite-granodiorite sheets which have yielded ages of ca. 2.7 Ga and 2.8 Ga respectively. Pegmatoidal, K-rich granite (termed the Igukshuak granite) cuts all the above units post-tectonically and was emplaced circa 2.5 Ga (Badsgaard et al., 1979). The final major event in the evolution of the Nain Province was the emplacement of a late Archean to early Proterozoic swarm of diabase dikes.

All the major lithologic units identified in the Saglek map area (Ryan et al., 1983) can be traced into the Hebron Fiord sector. However several differences from the Saglek area are noted:

1. In the Hebron Fiord sector, the gneisses east of the Handy Fault were subjected to a granulite facies event (Ryan, 1977) equated with the 2.8 Ga high grade metamorphism and reworking of earlier crustal material seen west of the Handy Fault at Saglek (Kerr, 1980; Collerson et al., 1981; Collerson, Kerr et al., 1982). Areas with relict granulite assemblages occur sporadically east of the fault just north of the present study area (Ryan et al., 1983), but the evidence for this high grade reworking is more widespread in the Hebron area indicating that deeper crustal levels are exposed in the eastern Archean block of this area. This granulite facies metamorphism is not developed to the same degree as in the block west of the Handy Fault however, so the area probably represents a zone intermediate or transitional between amphibolite and granulite facies.

2. Extensive areas of Uivak gneisses unaffected by younger events are not as common east of the Handy Fault in the Hebron area as in the Saglek area. In the Hebron area the old gneisses are preserved only as small septa on the order of a few tens of metres wide within younger migmatites. These younger migmatites, however, are derived by regional crustal reworking of the Uivak gneisses. These were termed Iterungnek gneisses by Ryan (1977), and their development is considered coeval with that of the Kiyuktok gneisses of Kerr (1980) and Collerson, Kerr et al. (1982). However, in contrast to the Kiyuktok gneisses, which are mostly a static reconstitution of the Uivak gneisses, the equivalent rocks east of the Handy Fault at Hebron appear to have developed under structurally dynamic conditions, probably reflecting their slightly higher crustal level of development.

3. South of Hebron Fiord, metasedimentary rocks of the Upernavik supracrustals occupy more than 30% of the granulite terrane west of the Handy Fault, and mafic metavolcanic and intrusive rocks are less abundant than at Saglek. This indicates that significant amounts of metasedimentary supracrustal material were tectonically emplaced to deep crustal levels in the Nain Province in the Archean, and may have implications regarding the origin of a distinctive garnet-rich tonalite gneiss in the adjacent Churchill Province. Granitoid melts in these Upernavik paragneisses are similar in composition to the garnetiferous tonalites, and it is conceivable that the parental tonalite for the Churchill rocks could have been derived by widespread Archean deep crustal melting of continental lithosphere which contained very large amounts of metasedimentary material (Ryan et al., 1983).

4. An extensive unit of coarse grained, undeformed to gneissic tonalite occurs along the western margin of the Nain Province (Churchill foreland zone) north of Hebron Fiord. This unit locally contains xenoliths of polydeformed quartzofeldspathic gneiss and mafic pods of diverse origin. It may be correlative with the Ikarut gneiss (Collerson, Kerr et al., 1982), an augen gneiss derived from porphyritic tonalite on the north shore of Hebron Fiord southwest of Freytag Inlet. A pre-Proterozoic age is indicated because, although tectonically interleaved with the Ramah Group, it does not intrude the group. It also forms the protolith material for the ultramylonite which defines the eastern boundary of the Churchill mobile zone.

5. Synkinematic to post-kinematic granitoid rocks appear to be areally more abundant here than at Saglek. In the northern area, younger granitoid rocks tend to occur only as isolated sheets or as parallel or crisscrossing networks, for instance the Saglek sheets and Igukshuak granite of Collerson, Kerr et al. (1982). Here however the granitoids are much more conspicuous. They vary from white, medium grained, homogeneous garnet and orthopyroxene-bearing varieties, as found north of Hebron village, to coarser porphyritic charnockites within metasediments 10 km south of Winnie Bay. An extensive unit of gray foliated tonalite to granodiorite similar to the Saglek sheets occurs subconcordant to the regional foliation east of the Handy Fault south of Hebron Fiord. Narrow lensoid units of white garnetiferous granite occur in the southern half of this eastern block.

6. The late Archean - early Proterozoic dikes are less abundant in the Hebron area than in the area to the north.

Churchill Province

The dominant rock type in the Churchill Province is a uniform leucocratic, garnet-rich quartzofeldspathic gneiss of tonalitic composition, which can be shown locally to be derived from an igneous protolith (e.g. an equigranular, medium grained tonalite, and white garnetiferous pegmatite). However, rusty garnet-graphite-rich layers appear to be relicts of metasedimentary material. These gneisses occupy a 15 km wide belt trending roughly north-northwest through the central part of 14L/3. The garnetiferous tonalitic gneiss generally appears coarse grained, but mineral subdomains are polycrystalline and highly elongated due to very strong deformation (Ryan et al., 1983). Even though in most places compositional layering and the conspicuous lenticular quartz fabric are parallel, examples are not uncommon of the quartz fabric oblique to layering, and of small folds of the layering with the quartz fabric as the axial planar foliation and lineation. Minor, but persistent and significant components in the garnetiferous gneiss belt in the present study area are garnetifeorus mafic and ultramafic granulites, some of which can be traced several kilometers along strike even though they are only 5 to 50 m thick. Their distribution is probably a function of isoclinal folding and repetition of only a few such individual units; such fold patterns can be seen most easily in the gneiss belt in the southern part of the area where macroscopic fold closures are locally preserved (Figure 2).

Hypersthene bearing, buff to brown weathering, quartzofeldspathic gneisses occur along the eastern and western borders of the white tonalite gneiss. These gneisses contain rare bands of mafic gneiss and garnet-bearing gneiss similar to those described above. At both margins the contact with the white garnetiferous tonalite gneiss is gradational, and in coastal exposures along inner Hebron Fiord, the tonalite is apparently intrusive into the hypersthene gneiss. In this area as well, the easternmost gneiss can be clearly demonstrated to have been derived by pervasive Proterozoic reworking of the Kiyuktok gneisses which occur in the adjacent Nain Province. The origin of the western unit is not as obvious; in fact in places it appears to have been originally a fine grained hypersthene granite which lacks compositional layering but displays the pronounced rodding lineation common to the Churchill Province rocks in this area.

Ramah Group supracrustal rocks occupy two narrow belts north-northwest of Freytag Inlet. The western band comprises strongly deformed quartzite with a single 1 m layer of amphibolite; the eastern band comprises quartzite with a central layer of pelitic (muscovite-biotite) schist. These lithologies are considered to be tectonized members of the basal part of the Ramah Group, the Rowsell Harbour Formation (Knight and Morgan, 1977; Morgan, 1975a), which have been interleaved with reworked Archean basement during the Hudsonian Orogeny. No Ramah Group rocks were found south of the northwest trending fault through Freytag Inlet.

Structure and Metamorphism

There is an obvious structural contrast between the Nain Province and Churchill Province (Figure 2). The Nain is typified by alternating orthogneiss and supracrustal gneiss units with a general northwest grain, locally displaying dome and basin fold patterns which are dissected by faults. Layering and fold axes are commonly steep, with the most obvious exception being a compositionally layered mafic gneiss (metagabbro) with metasedimentary screens which occupies a recumbent structure west of Kangerdluarsuksoak Inlet. The Churchill Province on the other hand lacks this closely alternating polylithological pattern but instead is typified by broad orthogneiss belts containing only minor amounts of other rock types with a steeply dipping north-northwest trend, and in which the intensity of Hudsonian deformation has destroyed or effectively masks any fold closures. A very prominent feature of the Churchill Province gneisses is a subhorizontal mineral rodding lineation within foliation planes, chiefly defined by gray quartz, but also by graphite smears and minute rutile needles. Ramah Group in the eastern Churchill Province is structurally interleaved with retrogressed Archean basement. Its distribution seems to be the result of refolding of basement-cover thrust slices (Ryan et al., 1983).

Metamorphic rocks exhibit amphibolite or granulite facies assemblages throughout the study area. The Archean terrane of the Nain Province east of Handy Fault is transitional between amphibolite and granulite facies; the most obvious indicator of this is coarse orthopyroxene grains in pegmatoidal sweats in mafic rocks and diffuse orthopyroxene- and garnet-bearing pegmatites emplaced syntectonically with the reworking of the Uivak gneisses (*cf.* Ryan, 1977). Retrogressed quartzofeldspathic rocks in this area have a green "blebby" aspect where orthopyroxene has been replaced by green biotite. West of Handy Fault the granulite aspect of the Archean rocks is more obvious: mafic rocks are friable and the quartzofeldspathic rocks are brownish weathering and are greenish brown on broken surfaces. However, within this terrane there are narrow belts of retrogression to amphibolite facies which have abrupt contacts with the surrounding granulites. Sillimanite and garnet are ubiquitous in paragneisses throughout the map area; cordierite has also been locally identified.

In the Hudsonian foreland zone east of the Ramah Group (Figures 1c, 2), the Archean granulite facies gneisses exhibit an amphibolite facies overprint, and the diabase dikes are foliated and converted to amphibolites.

The part of the Churchill Province containing the Ramah Group, (Figures 1c, 2) exhibits amphibolite facies metamorphism: sillimanite and kyanite have been identified in the pelitic schists just north of the study area, the granulite facies basement is retrogressed to amphibolite facies gneisses and schists, and diabase dikes are transformed into amphibolites and rotated subparallel to an attenuated Archean layering.

In the Churchill Province mobile zone (Figure 1c) the consistent occurrence of orthopyroxene in tonalitic and mafic gneisses clearly demonstrates granulite facies conditions during Hudsonian deformation. It is unclear, however, whether the orthopyroxene was produced by Hudsonian metamorphism or is an Archean paragenesis which was simply modified into the Churchill Province fabric by "dry-reworking" of the Archean terrane during the Proterozoic. Directly adjacent to the western contact of the pseudotachylite ultramylonite on the eastern margin of the mobile belt (Figure 2), hornblende is abundant and orthopyroxene rare, indicating transition to amphibolite facies.

Nature of the Nain-Churchill Boundary

The definition of a discrete boundary between the Nain and Churchill Provinces entails all the problems inherent in establishing rigid demarcation lines in juxtaposed orogenic belts (*cf.* Gower et al., 1980, page 785). The following features are considered in outlining the Nain-Churchill boundary in this area.

In the easternmost Archean terrane, with the possible exception of the faults there is no mesoscopic indication of penetrative Hudsonian deformation (eg. the discordant late Archean - early Proterozoic diabase dikes are neither schistose nor metamorphosed) although the isotopic systems are disturbed (Collerson, Brooks et al., 1982). In the western part of the Archean block, however, the effects of Hudsonian deformation can be discerned in (i) the transformation of the daibase dikes to "greenstones" and schistose amphibolites, even though they retain their primary discordance with gneissic layering, (ii) the westward retrogression of granulite facies Archean gneisses to amphibolite grade, and (iii) folding and shearing of post-tectonic pegmatites in the gneisses. We also tentatively assign the regional deformation of the lenticular grey tonalite west of Freytag Inlet to the Hudsonian Orogeny. Likewise we attribute all the north to north-northwest trending faults in this sector to Hudsonian deformation. It is on the basis of these observations that we have outlined the "foreland zone" to the Churchill Orogen shown in Figure 1c.

The "Churchill Province mobile zone" (Figure 1c) corresponds to Morgan's (1975a) definition of the "Churchill Province." It comprises two domains: (i) the Ramah Group and its reworked Archean basement, confined to the area northwest of Freytag Inlet, and (ii) the high grade gneisses. The gneisses are separated from the Ramah Group in the north and from the foreland zone in the south of the study area by a major belt of ultramylonite up to 100 m wide. This ultramylonite is a dark grey to black "vitrophyric" rock characterized by large (1 cm) feldspar porphyroclasts and hornblende porphyroblasts in an aphanitic matrix. Later brittle deformation produced abundant pseudotachylite in this rock and the gneisses immediately west and east of it. On approaching the ultramylonite zone from the gneisses to the west, there is a metamorphic change in the easternmost quartzofeldspathic granulite (Figure 2) such that orthopyroxene becomes subordinate to hornblende without any change in structure. Adjacent to the mylonite, however, the subhorizontal linear fabric characteristic of the Churchill Province gneisses is abruptly replaced by steep westerly plunging lineations indicating eastward directed thrust movement.

In summary, then, the Archean-Proterozoic boundary in the Hebron area can be defined in the same terms as that of the Saglek area to the north, in being a 2 to 5 km wide zone superimposed on the Nain Province in which the Archean and early Proterozoic rocks are overprinted by Hudsonian deformation upon approaching a fault-bordered block of gneisses with pronounced Hudsonian fabrics.

Economic Geology

Hand-held scintillometer surveys and limited ultraviolet light investigation failed to reveal radioactive or scheelite mineralization. Pyritic zones are locally present in the metasediments, and graphite seams occur in granulite facies rocks in the Churchill Province, but none appear to be of economic importance.

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PRELIMINARY RESULTS OF MAPPING IN THE RAMAH GROUP AND ADJACENT GNEISSES SOUTH OF SAGLEK FIORD, NORTHERN LABRADOR

by

F.C. Mengel[1]

Abstract

The predominantly metasedimentary Aphebian Ramah Group, which lies along the junction of the Nain and Churchill Provinces in northern Labrador, is transected by the north trending Hudsonian Front. In the east, rocks of the Ramah Group are autochthonous and lie undeformed on Archean gneisses, whereas in the west they are variably deformed and metamorphosed, and were transported eastward during Hudsonian thermotectonism.

Metamorphic grade in the Ramah Group increases from greenschist facies in the east to amphibolite facies in the west and south, and from north to south there is a significant increase in structural complexity. The westerly increase in metamorphic grade reflects the Hudsonian metamorphic zonation, subsequently telescoped by west dipping thrust faults which carried higher grade rocks on top of lower grade rocks. The southerly increase in metamorphic grade and structural complexity is believed to be a result of crustal tilting.

Early subhorizontal thrusting was probably synchronous with the development of the regional S_1 *fabric, and both* S_1 *and* D_1 *thrusts were refolded during* D_2 *into north trending folds with gently north or south plunging axes and vertical to west dipping axial planes. Later thrusting along west dipping surfaces truncated* F_2 *folds. Locally a* D_3 *event produced northwest trending folds with subhorizontal axes. These* F_3 *structures may be related to subhorizontal transcurrent shearing along the Hudsonian Front, as indicated by the penetrative subhorizontal linear fabric in mylonitized rocks west of the Ramah Group. The peak of metamorphism was probably reached during* D_2*.*

Introduction

This report presents preliminary results of field observations and mapping in the area south of Saglek Fiord (Figure 1). Efforts were concentrated on the Aphebian Ramah Group and to a lesser extent on the adjacent gneisses.

The general aim of this study is to establish the nature and extent of Hudsonian deformation and metamorphism along the boundary of the Nain and Churchill Provinces as recorded by the Ramah Group and adjacent gneisses. Work in 1984 will concentrate on the Hudsonian effects on the Archean gneisses and the early Proterozoic dike swarm (2300-2400 Ma; Fahrig, 1970; Taylor, 1974; Ryan et al., 1983) that occur on both sides of the Ramah Group.

Geological Setting

Rocks of the Ramah Group are dominantly of sedimentary origin (Morgan, 1975; Knight and Morgan, 1981) and occupy a north trending fold belt in northern Labrador (Figure 1). To the east the group unconformably overlies Archean gneisses with along and complex pre-Ramah history (Morgan, 1975; Bridgwater et al., 1975; Collerson et al., 1976; Collerson and Bridgwater, 1979; Ryan et al., 1983, 1984 in this volume). Gneisses west of the Ramah Group belong to the Churchill Province and are chiefly rocks of Archean age, reworked during the Hudsonian Orogeny (Bridgwater et al., 1975; Morgan, 1975; Ryan et al., 1983, 1984 in this volume; Wardle, 1983).

The Ramah Group was variably deformed and metamorphosed during the Hudsonian Orogeny. In the present study area gradients of increasing deformation and metamorphism have been reported from east to west and from north to south (Morgan, 1975; Ryan et al., 1983, 1984 in this volume).

Description of Rock Units

Basement Rocks in Nain Province, East of Ramah Group

In the northern area (Figure 2) the Archean basement comprises banded gneisses of granitic to tonalitic composition, mafic

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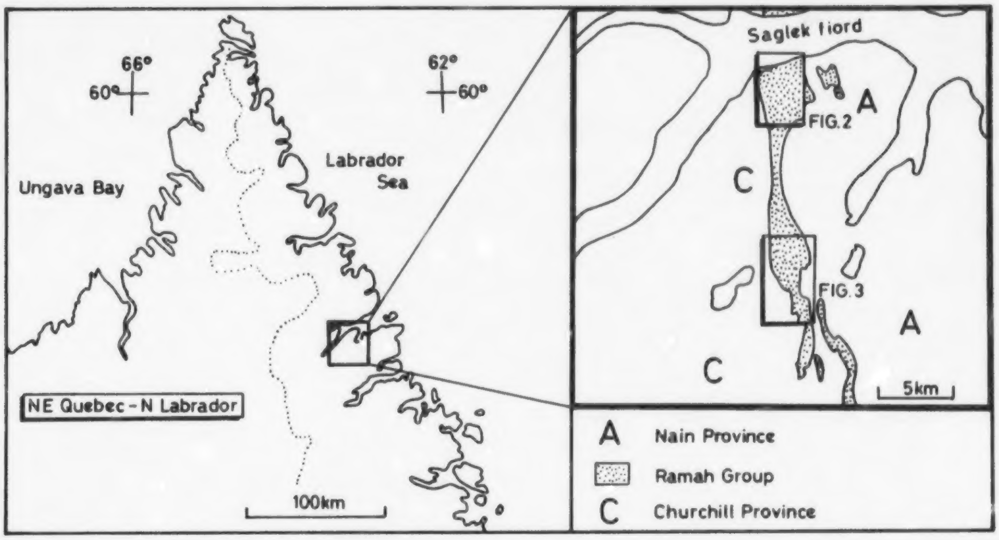


Figure 1: *Sketch map of northern Labrador showing the location of the study area. The extent of the Ramah Group is from Ryan et al. (1983).*

granulites and granitoids. In the southern area (Figure 3) the basement gneisses are well layered and predominantly of granodioritic to dioritic composition. In both the northern and southern area the observed contacts with the Ramah Group are tectonic, and the original unconformity was not recognized.

Banded gneisses. This is a compositionally variable unit, being predominantly granitic to tonalitic in the northern area, and granodioritic to dioritic in the southern area. The gneisses possess a millimetre to centimetre scale compositional layering defined by alternating felsic and mafic layers, which is parallel to a foliation defined by the parallel alignment of biotite grains.

In the southern area the gneisses are more strongly tectonized, especially in the region of the contact with the Ramah Group where they are darker in color, strongly mylonitized and schistose, and amphibolites within the gneisses are converted to hornblende schists.

Inclusions within the gneisses include minor pegmatitic and mafic components; a small talc-serpentine outcrop is believed to be an altered ultrabasic lens. Recognizable mafic metadikes are completely recrystallized and contain hornblende, plagioclase and minor sulfides. These amphibolites frequently contain centimetre scale lensoid augen, presumably plagioclase, and are believed to belong to the early Proterozoic dike swarm.

The *mafic granulite* unit comprises fine to medium grained rocks consisting of hornblende, plagioclase, garnet and quartz. Pegmatoid sweats frequently contain large garnets (10 to 20 mm) and brown clots thought to be relict orthopyroxene. These rocks are seen to be cut in one place by a pegmatitic gray gneiss identical to the tonalitic gneiss described above. Microstructurally these mafic rocks vary from isotropic to well layered on a millimetre to centimetre scale. Where sheared, the rocks are fine grained and display a fine laminar banding.

The *granite (sensu lato)* varies in composition from alkali granite to granite, the mafics never exceeding 1% (biotite). The rock is medium grained and isotropic.

The *granodiorite (sensu lato)* varies from granodiorite to tonalite in composition, and is composed of quartz, plagioclase, hornblende and minor alkali feldspar. Veins of granodiorite cut the mafic granulite, but boundaries are not sharp, indicating that both units underwent postinjection recrystallization. The boundary is cut by mafic metadikes with white lensoid augen and recognizable plagioclase

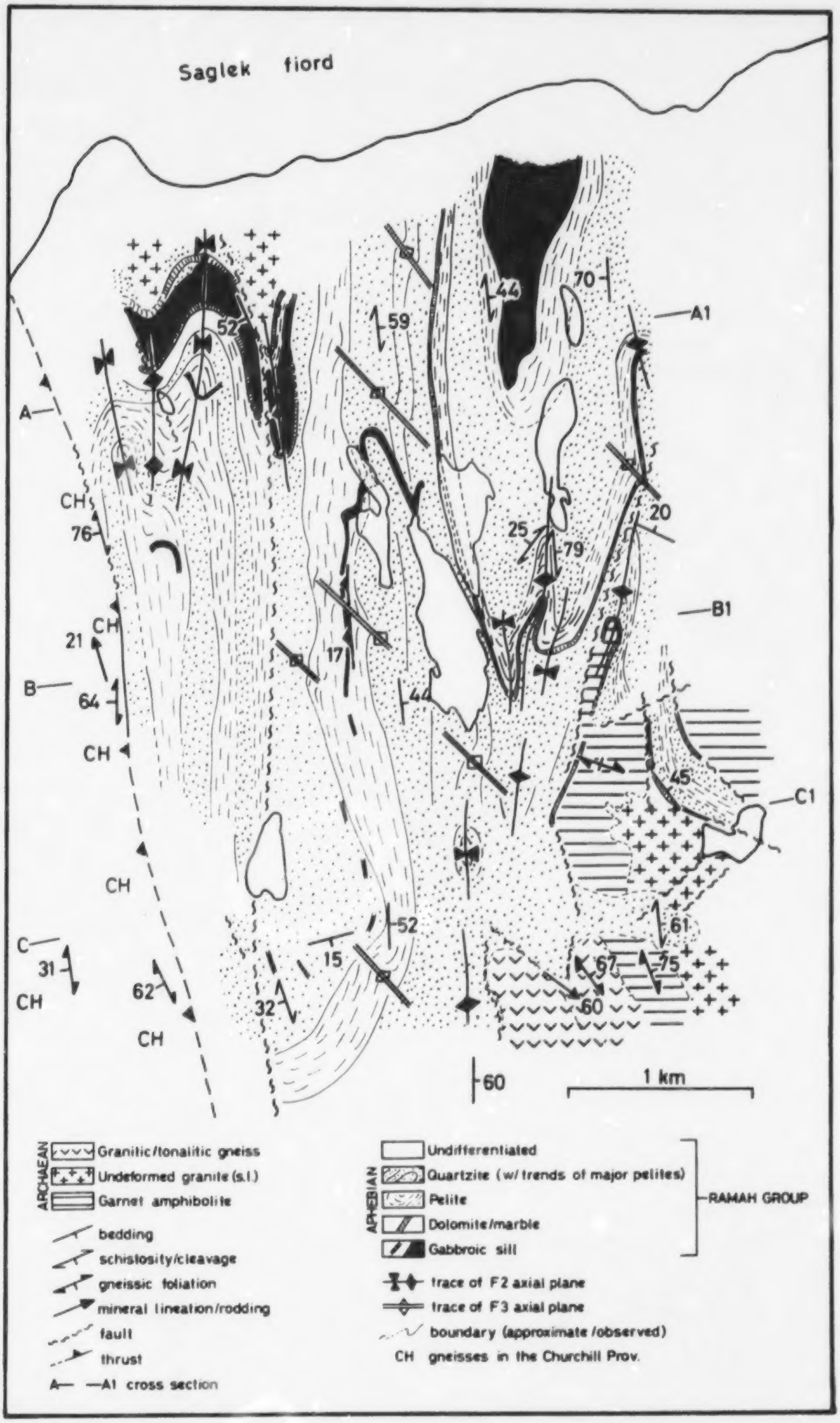
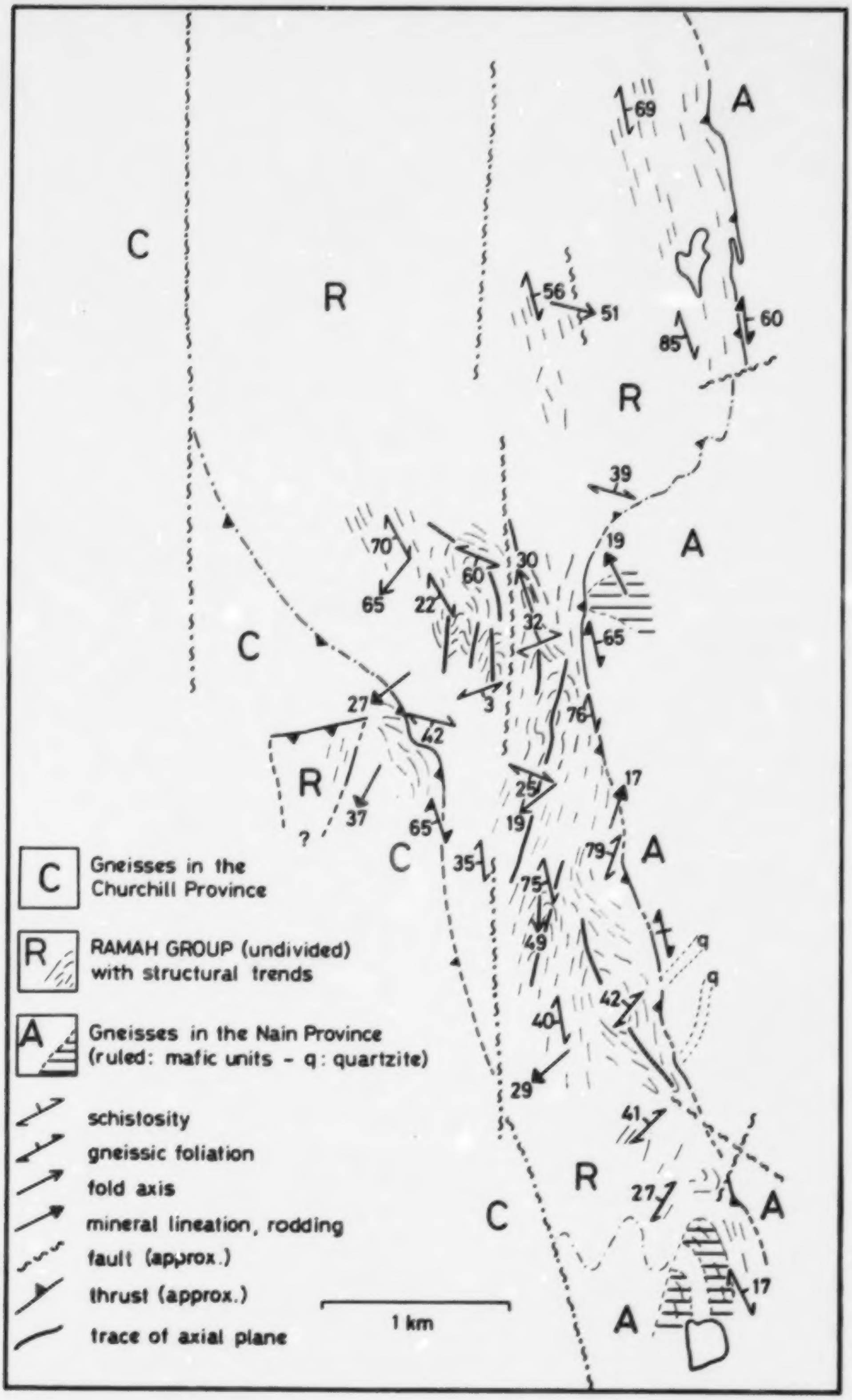

Saglek fiord
A
A1
B
B1
C
C1
CH
52
59
44
70
76
21
64
17
44
25
79
20
45
61
67
75
60
52
15
32
31
62
1 km
Granitic/tonalitic gneiss
Undeformed granite (s.l.)
Garnet amphibolite
ARCHAEAN
bedding
schistosity/cleavage
gneissic foliation
mineral lineation/rodding
fault
thrust
A— —A1 cross section
Undifferentiated
Quartzite (w/ trends of major pelites)
Pelite
Dolomite/marble
Gabbroic sill
APHEBIAN
RAMAH GROUP
trace of F2 axial plane
trace of F3 axial plane
boundary (approximate/observed)
CH gneisses in the Churchill Prov.

Figure 2: *Generalized geological map of the northern area (see Figure 1 for location). Minor pelite layers have been omitted in the quartzites. Cross-sections (Figure 4) are indicated by A-A1, etc..*


C
R
A
R
A
C
R
C
A
C
R
A
A
69
56
51
60
85
39
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60
30
65
22
32
65
27
3
42
76
17
25
19
37
65
35
79
75
49
42
40
29
41
27
17
?
q
q
C Gneisses in the Churchill Province
R RAMAH GROUP (undivided) with structural trends
A Gneisses in the Nain Province (ruled: mafic units - q: quartzite)
schistosity
gneissic foliation
fold axis
mineral lineation, rodding
fault (approx.)
thrust (approx.)
trace of axial plane
1 km

Figure 3: *Generalized structural map of the southern area (see Figure 1 for location). Structural trends are mainly from pelites. All symbols of the dash-dot type are from Ryan et al. (1983).*

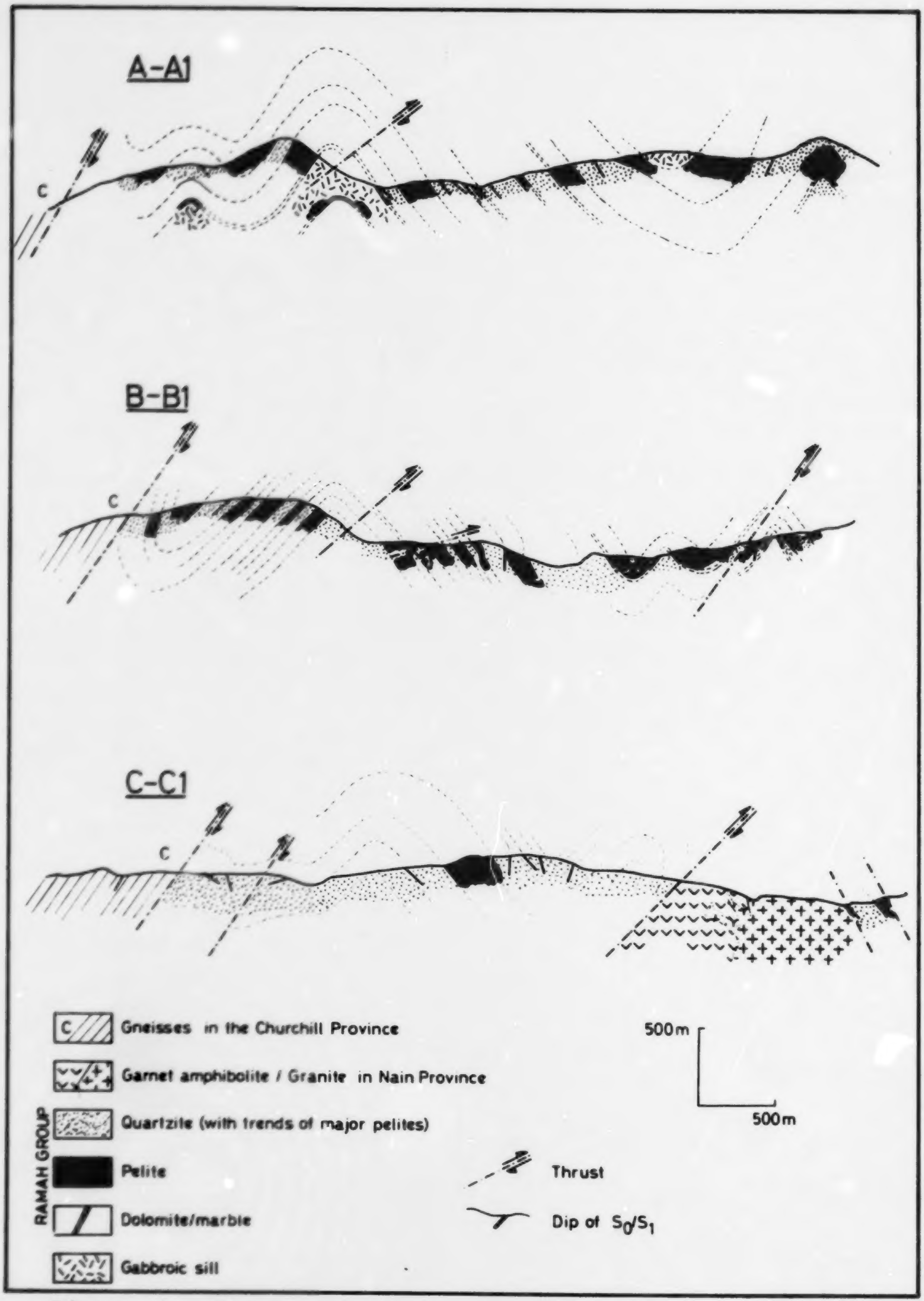
A-A1
C
B-B1
C
C-C1
C
C Gneisses in the Churchill Province
Garnet amphibolite / Granite in Nain Province
RAMAH GROUP
Quartzite (with trends of major pelites)
Pelite
Dolomite/marble
Gabbroic sill
500m
500m
Thrust
Dip of S_0/S_1

Figure 4: *Structural cross-sections of the Ramah Group in the area (Figure 2). Note the change in lithological symbols from Figure 2. Several of the pelites displayed in B-B1 are not distinguished on the map (Figure 2).*

laths. These dikes presumably belong to the early Proterozoic dike swarm.

Gneisses in Churchill Province

Gneisses in the Churchill Province are broadly similar to those in the Nain Province, but underwent an additional tectonothermal event of Hudsonian age in amphibolite to granulite facies.

They are gray biotite gneisses of granitic to tonalitic composition, with millimetre to centimetre scale compositional layering. Mafic metadikes in the gneisses are garnet amphibolites, in many cases with hornblende mantling orthopyroxene, indicating that the rocks experienced retrogression after a granulite facies metamorphic event. The metadikes may represent deformed and metamorphosed Saglek dikes (3000 to 3600 Ma; Bridgwater et al., 1975) but are probably metamorphosed members of the early Proterozoic dike swarm.

Near the tectonic contact with the Ramah Group, the biotite gneisses are strongly deformed and locally mylonitic. Well developed mineral lineations and rodding with shallow plunges are contained in the west-southwest dipping sheared contact. The lineations are compatible with transcurrent movements in the Hudsonian front zone. The implications of this will be discussed in a later section.

Ramah Group

Sedimentological and stratigraphic aspects have been treated in great detail by Morgan (1975) and Knight and Morgan (1981). They subdivided the ca. 1700 m sediments into six formations, of which only the lower three are represented in the study area. The Rowsell Harbour and Reddick Bight Formations comprise quartzite, pelite and dolostone of shallow shelf facies, recording several transgressive/regressive events. Following rapid subsidence, the deep water basinal Nullataktok Formation, composed mainly of black shales, was deposited. Locally a gabbroic sill intrudes the sedimentary pile at this level. The following sequence, found in the northeastern part of the study area, is thought to represent the transition from Reddick Bight to Nullataktok Formations: carbonate-cemented quartzite - black slate - Fe-sulfide-rich horizon - gabbroic sill. The large region with quartz-veined mica schist in the southern area (not distinguished on Figure 3, but see Ryan et al. (1983), Figure 41.3) is likewise thought to represent the Nullataktok Formation, but complex folding elsewhere in the southern area renders stratigraphic correlation tenuous.

Metamorphism

Earlier workers in the area (Morgan, 1975; Ryan et al., 1983, 1984 in this volume) have suggested that there is an increase in metamorphic grade both from east to west and from north to south in the area. Preliminary results of this study seem to confirm this zonation. In the northern area, microstructural changes in the gabbroic sill record the transition from well preserved ophitic igneous microstructure with recognizable plagioclase and clinopyroxene to an amphibolite with hornblende and recrystallized plagioclase. The presence of unmetamorphosed gabbroic dikes in the central part of the northern area strongly suggests postmetamorphic intrusion. Gabbroic rocks are not recognized in the southern area.

Metamorphic development is spectacular in the carbonate units. In the east, quartz and calcite-dolomite are in stable coexistence, and talc is only developed locally, indicating the reaction:

dolomite + quartz + H_2O = talc + calcite + CO_2

(Winkler, 1974, page 111 *ff*). In the west tremolite is developed, and a reaction such as

quartz + dolomite + talc = tremolite + CO_2

(Winkler, 1974, page 111 *ff*) is likely to have occurred. In the southern area talc is believed to be present in the east, whereas diopside occurs further west, suggesting that carbonates reacted with tremolite and quartz to form diopside and a fluid phase (Winkler, 1974, page 111 *ff*).

Details of metamorphic reactions occurring in the pelites are at present being studied, but generally the highest grade recorded by the pelites is represented by kyanite and staurolite (identified in thin section) and andalusite (identified in hand specimen) in the western part of the area. To the east the pelites may contain biotite and/or muscovite with chlorite. These preliminary observations suggest a change from greenschist facies in the east to amphibolite facies in the west. Judging from distribution of the mineral assemblages, the metamorphic grade changes rather rapidly in the central part of the area; these abrupt changes may indicate the presence of thrust faults.

In the southern area, garnet (with muscovite and biotite) is present in all pelites, the only indication of a metamorphic gradient being the presence of talc in the carbonates to the east.

Structures

Northern Area

S_0 is recognizable throughout and occurs as compositional or laminar bedding or as color differences, and current bedding and ripple marks are preserved. D_1 produced a regional S_1 parallel to S_0. D_1 has been interpreted from results of regional mapping as an episode of extensive eastward subhorizontal thrusting producing a regional S_1 (Ryan, personal communication, 1983). F_1 would thus likely be preserved as asymmetrical intrafolial folds, but these and other evidence supporting the above interpretation (e.g. strong L_1 lineations) were not observed. S_1 may be described as a slaty or phyllitic cleavage in the lower grade rocks, and a schistosity in the mica schists.

During D_2, mesoscopic and macroscopic north striking F_2 folds (Figure 4) with vertical to west dipping axial planes were developed. F_2 fold axes are gently north or south plunging. D_2 also produced small scale crenulations giving rise to pronounced D_2 crenulation lineations, small fold axes, mineral lineations and rodding. All L_2's are parallel to F_2 fold axes. S_2 is locally, but not extensively developed. D_3 formed local mesoscopic asymmetrical northwest trending folds with subhorizontal axes, open antiforms and tight synforms (See Figure 2). D_3 clearly folded structures produced by D_2. L_3 is seen as small folds and crenulation lineations. S_3 is only sporadically developed. A significant population of north-northeast to northeast plunging crenulation lineations and small fold axes may represent a D_4 episode, but may also be L_2's rotated during D_3.

D_2 structures are believed to have formed in response to the eastward movement of the rocks west of the Ramah Group. This orientation of the stress field is in accordance with eastward directed thrusting (Figure 4).

The eastward thrusting occurred late in the D_2 since several D_2 structures are truncated. Linear fabrics compatible with eastward thrusting are not preserved, and the subhorizontal lineations observed in the Churchill-Ramah boundary provide evidence for transcurrent movements postdating the thrusting. Formation of the D_3 structures is in accordance with transcurrent (dextral?) movement along the Hudsonian front.

At least two episodes of gabbro intrusion can be documented. In the northern area, the minimum 10 m thick sill is subhorizontal and more or less parallel to stratification. The rock is metamorphosed, and the primary minerals are now converted to hornblende, recrystallized plagioclase, epidote and chlorite. The sill was probably emplaced pre- or syn-D_1. Further west and southwest the gabbroic dikes are 1 to 10 m wide and have variable orientation. The dikes cut across S_1 but are folded by D_2, so intrusion must be pre- or syn-D_2. Preliminary observations indicate that these dikes are unaffected by metamorphism, thus suggesting that penetrative metamorphism and deformation ceased sometime during D_2.

Southern Area

The structures in this area (Figure 3) have not been investigated in detail, but a few general statements can be made.

All boundaries between the Ramah Group and adjacent gneisses are tectonic, and structural data suggest that they have been modified by later folding and thrusting. Along the western margin of the Ramah Group, mineral lineations and rodding plunge systematically southwest in accordance with northeast directed thrusting. At the time of writing it is not known whether this is part of the main thrusting event (and thus comparable with the eastward thrusting recorded in the northern area) or represents a later kinematic episode. The latter hypothesis is favored by the roughly north trend of axial planes: structures of this orientation are unlikely to have formed contemporaneously with northeast directed thrusting. The general north trend of axial planes is comparable to the D_2 structures in the northern area, and suggests that the southern area also experienced a period of folding with north trending axial planes possibly followed by eastward thrusting.

Discussion

The following general observations have been made:

(1) structural complexity increases from north to south;

(2) metamorphic grade increases from east to west and from north to south.

Figure 5 shows a schematic cross-section of the Nain-Churchill boundary and the overlying Ramah Group. The section X-X represents the structural level presently exposed immediately south of Saglek Fiord (compare with cross-sections, Figure 4) and

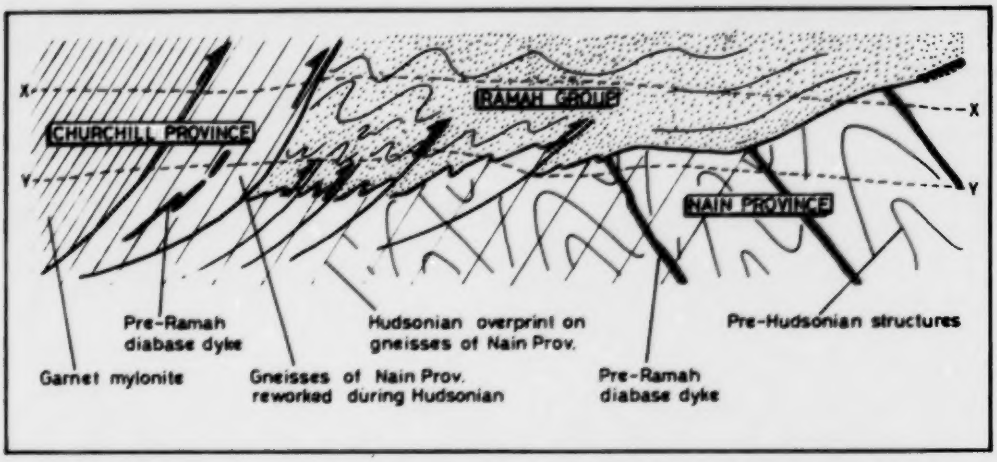

Figure 5: *Schematic cross-section of the Nain-Churchill boundary and the overlying Ramah Group illustrating the structural and metamorphic changes recorded from the northern area (level X-X) to the southern area (level Y-Y). The unconformity between the Ramah Group and the Archean basement is indicated in the top right hand corner. Trend lines in the Ramah Group are* S_1. *Thrusts postdate* S_1. *Based partly on Ryan et al. (1983) and Wardle (1983).*

the deeper level Y-Y is believed to represent the more complex southern area. Post-Hudsonian crustal tilting, exposing deeper levels in the southern area, can explain the above general observations, and is also in accordance with the drastic thinning and eventual disappearance of the Ramah Group further south towards Hebron Fiord (Ryan et al., 1984 in this volume).

Economic Geology

Near the base of the Nullataktok Formation, a sulfide horizon occurs where the gabbroic sill intrudes the black slate. The horizon was described by Knight and Morgan (1981), Ryan et al. (1983) and Wardle (1983), and comprises a massive to bedded fine grained pyrite-pyrrhotite horizon with pebbles of quartzite, chert and slate. The occurrence is not of economic importance in itself, but does indicate the presence of sulfide-generating processes in the Ramah basin at the time of deposition.

Acknowledgements

I would like to thank Toby Rivers for suggesting the study area, and Bruce Ryan and David Bridgwater for introducing me to the general geology of the Saglek area. Discussions and constructive criticism by Bruce Ryan and Toby Rivers improved the manuscript and my understanding of the metamorphic and structural development.

Field work was carried out in cooperation with a regional mapping program in the Saglek-Hebron area (see Ryan et al., 1984 in this volume, for details).

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GEOLOGY OF THE ATIKONAK LAKE AREA, GRENVILLE PROVINCE, WESTERN LABRADOR

by

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Also *in* Current Research, Part B, Geological Survey of Canada, Paper 84-1B.

Abstract

The map area lies within the Grenville Province in southwestern Labrador and an adjacent part of Quebec. High grade pelitic to semipelitic gneiss is predominant and is intercalated with minor basic paragneiss. The paragneiss is intruded by a basic plutonic suite and a younger acidic plutonic suite. Anorthositic rocks outcrop in the southeast part of the map area; the age and contact relationships of the anorthositic suite are unknown.

Age dating of probably related, and in some cases equivalent, rock units to the north and northeast indicate a polyorogenic history for the map area. The paragneiss was affected by an older event that was separated from a younger orogenic event by the emplacement of the basic and acidic plutonic suites. Probable equivalents of the acidic suite yield ages of circa 1654 Ma. The paragneiss and the plutonic suites were later affected by a series of tectonic episodes, which locally attained granulite facies pressures and temperatures, dated at circa 1646 Ma and termed here the Labradorian orogeny.

The effect of the Grenville Orogeny in this part of the Grenville Province is presumed to consist of low grade thermal features and brittle deformation, possibly with considerably higher grade events in localized ductile shear zones.

Introduction

This report summarizes the results of 1:100,000 scale geological mapping carried out during 1983 in N.T.S. map areas 23A/9, 10, 15 and 16 (Figure 1).

The area centers around Atikonak Lake, which occupies a broad, shallow, drift-blanketed depression at an elevation of 550 to 600 m, from which the land rises to the east and northwest to a better exposed, deeply dissected peneplain at about 770 m. Atikonak Lake and many other large lakes allow float plane access to most of the lowlands, but large tracts of swamp and the mountains are mostly accessible only by helicopter.

Previous Work

Pyke (1956) reported the preliminary results of exploration by BRINEX throughout the area, which included geological reconnaissance in 1953, airborne geophysics in 1954 and ground prospecting in 1956. BRINEX found widespread but minor occurrences of Fe, Ti and Cu mineralization.

Stevenson (1968) mapped the area at 1:250,000 scale and determined it to be largely underlain by quartzofeldspathic, sillimanite-bearing paragneisses with minor amounts of gabbroid, granitoid and anorthositic rocks. He noted the particularly complex structure of the gneisses and the higher grade of those underlying the upland regions in this area. Stevenson's map was incorporated into the regional geological compilation of Labrador at 1:1,000,000 scale by Greene (1972).

The area has traditionally been regarded as lying well south of the Grenville Front zone and, by inference, as underlain by high grade Grenvillian gneisses (Stevenson, 1968; Greene, 1974; Smyth and Greene, 1976; Nunn and Christopher, 1983). Mapping carried out during 1982 established a polydeformational history for the paragneiss in the area to the north (Nunn and Christopher, 1983). Effects of the early episodes, which were tentatively assigned to the Hudsonian Orogeny and are recorded in the paragneiss as a folded gneissosity, are separated from the effects of later orogenies by the

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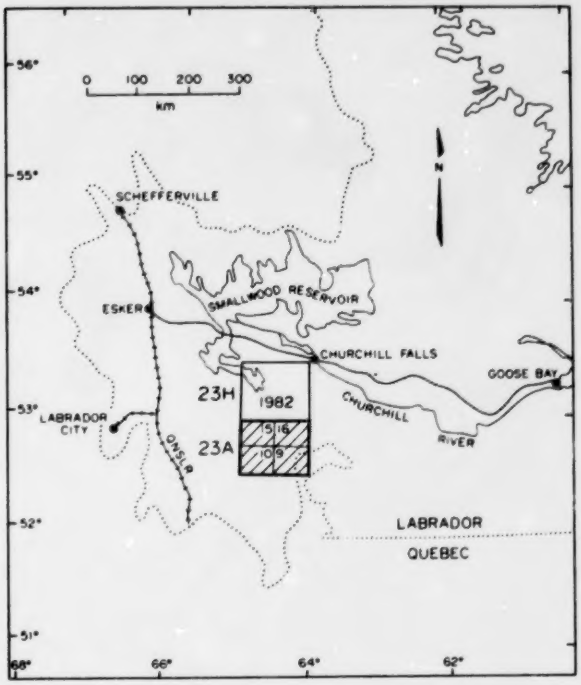


Figure 1. *Location map of the Atikonak Lake area, western Labrador.*

emplacement of granitoid and gabbroid plutonic suites. The later events, which were thought to reflect the Grenvillian Orogeny by Nunn and Christopher (1983), are manifested by further migmatization, a pervasive mineral recrystallization and several deformational episodes. These later events affected all the rock types in the area of Nunn and Christopher (1982 in Figure 1).

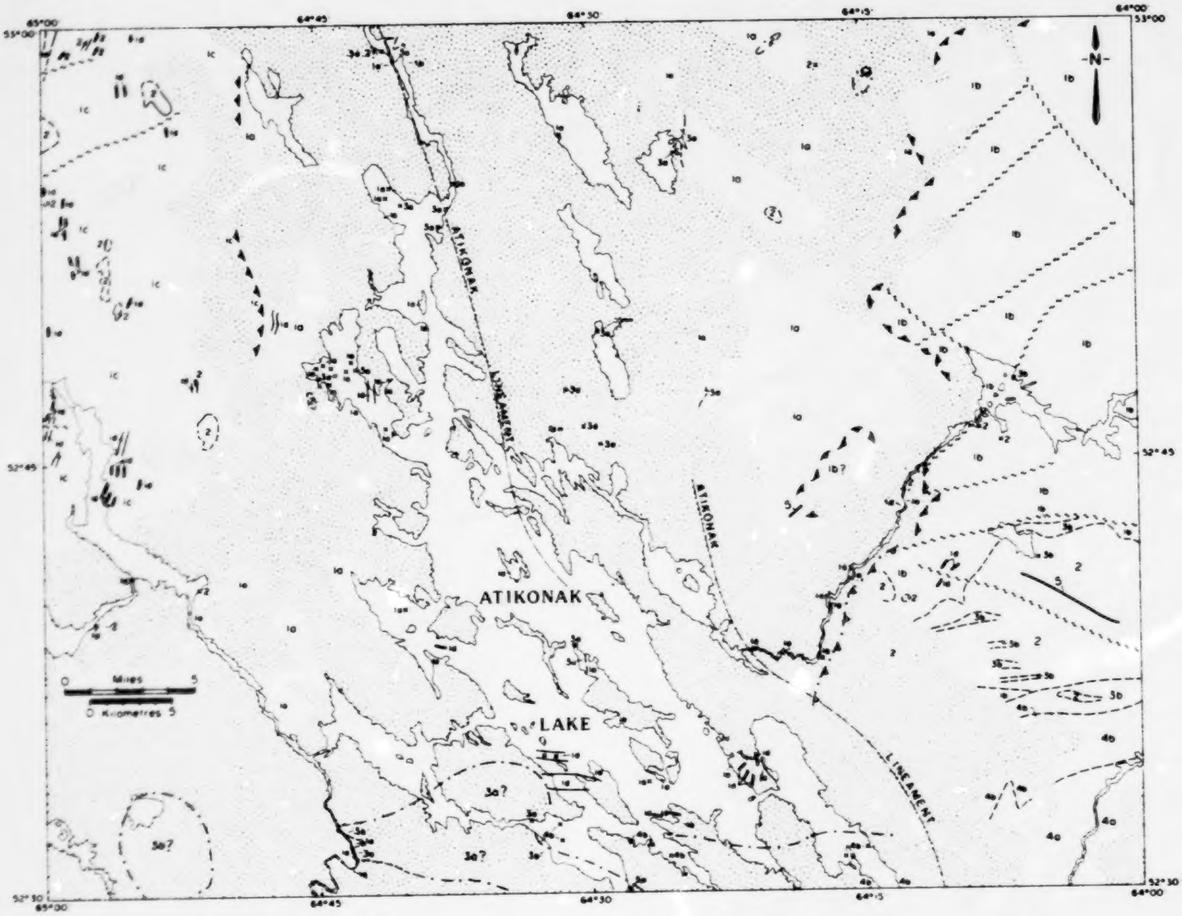
General Geology

Most of the map area (Figure 2) is underlain by sillimanite-bearing, quartzofeldspathic, pelitic to semipelitic paragneiss (unit 1) of three main subfacies. The differences between the subfacies are structural and textural, not compositional, and are considered to reflect a relationship between the structural development of the paragneiss and the grade and timing of peak metamorphism. The metamorphic grade is determined from the associated plutonic suites (units 2 and 3) in each subfacies area. The central and southwestern lowland areas are underlain by upper amphibolite facies rocks (subfacies 1a) whereas the eastern and northwestern upland areas are underlain by granulite facies rocks (subfacies 1b and 1c, respectively). The boundaries between the subfacies are approximate and appear transitional. In previous work to the north, the boundaries were inferred to be thrust zones (Nunn and Christopher, 1983). The northwestern granulite facies paragneiss is structurally more like the amphibolite facies rocks than its eastern counterpart, and appears to have undergone peak metamorphism at a later stage than the eastern granulites.

Banded, supracrustal metabasic rocks and minor quartzite (unit 1d) form widespread but minor intercalations in the paragneiss. They are particularly abundant in the northwestern map area (23A/10). Throughout the Atikonak Lake area, these basic gneisses contain both orthopyroxene and clinopyroxene, and appear to consist of granulite facies assemblages even in the parts of the map area believed to be in the amphibolite facies.

The paragneiss is intruded by a gabbroid suite (unit 2) and a predominantly K-feldspar megacrystic granitoid suite (unit 3). The former is more abundant in the granulite facies parts of the map area, and the latter is more abundant in the poorly exposed amphibolite facies terrane. To the west of the area in map sheet 13D/12 (Thomas et al., 1984 (this volume)), charnockitic varieties of the granitoid unit (3b) are associated with and intrusive into noritic rocks (unit 2). This relationship has also been recognized to the northeast of this area in the Red Wine Mountains (Emslie et al., 1978). It is not known whether the generally weaker fabric development in the charnockitic rocks (unit 3b), in contrast to the basic plutonic suite (unit 2), reflects a different response to deformation or a structural event separating the two plutonic suites.

A rock equivalent to the unit 3b granitoid rocks from just north of the western part of the map area has given a U-Pb zircon core age of 1672 Ma (Krogh, written communication, 1983). Based upon continuity (Thomas et al., 1981; Wardle and Britton, 1981; Nunn and Christopher, 1983) and mineralogical composition and texture (Nunn and Christopher, 1983), the dated rock has been correlated by Nunn and Christopher (1983) with units to the north and northeast of the map area (e.g. North Pole Brook Intrusive Suite, Thomas and Hibbs, 1980; Michikamau plutonic suite, Nunn and Noel, 1982). These units have yielded ages ranging from circa 1700 Ma to 1576 Ma with a distinct cluster at approximately 1650 ± 20 Ma (e.g. Fryer, 1983; Krogh et al., in preparation). These data suggest an age of about 1670 Ma for the emplacement of the plutonic granitoid suite, and freezing of the U-Pb and Rb-Sr geochronological systems due to regional cooling following low grade to granulite grade metamorphism at around 1650 Ma.


65°00'
64°45'
64°30'
64°15'
64°00'
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52°45'
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-N-
ATIKONAK LAKE
ATIKONAK LINEAMENT
ATIKONAK
LINEAMENT
ATIKONAK
LAKE
0 Miles 5
0 Kilometres 5
1a
1b
1c
2
3a
3a?
3b
3b?
4a
4b
5
1b?

Figure 2: *Geology of the Atikonak Lake area.*

SYMBOLS

Thin layers and sheets, schematic (exaggerated) . . . . ━
Isolated outcrops or outcrop groups x
Geological boundary (approximate, inferred) . . . . ╱ ╱
Interpretative aeromagnetic boundary (geological, thrust) . . . . ╱ ▲
Faults and lineaments (inferred) . . . . ~~~~
Thrust, teeth on upthrust block (inferred) . . . . ▼▼▼
Atikonak lineament . . . . ╱

Legend for Figure 2

LEGEND

HELIKIAN **or younger**

5 *Diabase dykes.*

HELIKIAN

4 **Anorthosite suite:** *possibly approximately synchronous with Unit 2.*
4a - *anorthosite and noritic anorthosite.*
4b - *leuconorite.*

PALEOHELIKIAN

3 **Orthogneiss and foliated granitoid rocks:** *possible equivalents of the North Pole Brook Intrusive Suite (Thomas and Hibbs, 1980).*
3a - *K-feldspar megacrystic granodiorite and quartz monzonite and strongly deformed porphyroclastic equivalents; minor non-megacrystic granodiorite.*
3b - *opdalite and farsundite equivalents of 3a.*

2 **Basic plutonic suite:** *possible equivalents of the Ptarmigan Complex (Emslie et al., 1978). Primary or metamorphic textured gabbro to norite; partial to complete plagioclase-hornblende-biotite replacement in amphibolite facies areas.*

APHEBIAN

1 **Paragneiss:**
1a - *migmatite-banded pelitic to semipelitic amphibolite facies metasedimentary gneisses in central lowlands.*
1b - *granulite grade equivalents of 1a in the east.*
1c - *granulite grade equivalents of 1a in the west.*
1d - *metabasic gneisses with minor metasedimentary paragneiss layers and rare quartzite.*

The major metamorphic events which affected units 2 and 3 have been dated. The granulite facies metamorphism recorded in the same equivalent of the unit 3b granitoid rock (see above) has yielded U-Pb zircon concordia ages of 1645 and 1647 Ma (Krogh, written communication, 1983). Furthermore, U-Pb dating on sphene (Krogh et al., in preparation) from granitoid units throughout the Grenville Front Tectonic Zone to the north and the northeast of the map area has demonstrated fairly conclusively that the main upper amphibolite to granulite facies metamorphism occurred around or before 1650 Ma rather than during the Grenville Orogeny as previously thought. Tectonic features attributed to this Paleohelikian event, though not necessarily assigned thus by the authors at the time, are widespread in central Labrador and range from greenschist facies foliations to migmatites and gneissic fabrics. These structures are not confined to the high grade gneisses and migmatites of previous mapping (Thomas and Wood, 1983; Nunn and Christopher, 1983) and the Red Wine Mountains (Emslie et al., 1978) but extend farther north into lower grade rocks of the Trans-Labrador batholith (Ryan, 1980; Thomas and Hibbs, 1980; Nunn, 1981; Thomas et al., 1981; Nunn and Noel, 1982; Ryan et al., 1982). We have tentatively termed these events the Labradorian orogeny.

Equivalents of the plutonic suites yielding similar ages are known from a long belt subparallel to the northern margin of the Grenville Province, stretching from Scandinavia through Labrador to Mexico. In Labrador, these have been collectively termed the Trans-Labrador batholith (Wardle and staff, 1982); elsewhere, they include the Smaland-Varmland granitoid terrane in Sweden (Gower and Owen, in preparation) and the Mazatzal Belt in the United States (Van Schmus and Bickford, 1981). The only tectonic events of this age known to the authors are from the Mazatzal orogeny in the southwestern United States and from the American midwest (Van Schmus and Bickford, 1981). Along the southeastern margin of Laurentia the Labradorian orogeny may be only one of a series of localized to extensive "... repeated overprinting or overlapping of successive tectonic events ..." (Baragar, 1981). However, as more dates become available, in particular those from methods capable of seeing through the Grenvillian resetting, the orogeny may take on more than local significance.

Unit 4 consists of anorthosite (unit 4a) and leuconorite (unit 4b), and occurs only in the southeastern corner of the map area. The age of the anorthositic rocks is unknown, as is their position in the chronological sequence. The major shear zone which affects the northern margin of unit 4 could be Labradorian or Grenvillian in age.

Unit 1: Supracrustal Gneisses

Unit 1a consists of upper amphibolite facies metasedimentary paragneiss, and units 1b and 1c consist of equivalent granulite facies paragneiss. The hand specimen mineralogy of these paragneisses is typical of both facies, and their distinction relies on the mineralogy of the spatially associated plutonic rocks and their neosomes, and the structural morphology of the paragneisses.

The paragneisses are predominantly a monotonous sequence of pelitic to semipelitic migmatites. They consist of quartz + feldspar + biotite ± magnetite ± garnet migmatitic neosomes and sillimanite + biotite + opaque oxides ± plagioclase ± garnet restites. The early neosomes form a concordant layering which is cut across by later generations of similar material. Either the restite or the neosome may form disrupted layers within the other. Patches and dikes, up to 5 m thick, of diatexite containing small patches of restite indicate coalescing melt and local mobility of the neosome phase.

Homogeneous, nonmigmatitic, paleosome layers and thin, psammitic layers are uncommon relicts of the primary layering.

The quartzofeldspathic minerals commonly display a mineral fabric or static recrystallization textures. The restites always contain a mineral fabric, though this may be dynamic or mimetic.

Despite the monotonous compositional character of unit 1, it can commonly be subdivided on a structural basis. Unit 1a is composed mostly of tight, straight belttype structures. Unit 1b is characterized by more areas of irregular fabric, thicker, wavy layering and open folding and, in contrast to unit 1a, fewer zones of regular, attenuated, straight fabrics and tight folds. Structures in unit 1c are like those of 1a but the melt layering in the straight zones commonly exhibits porphyroclastic textures whereas that in units 1a and 1b is commonly annealed.

The basic gneisses (unit 1d) intercalated with the paragneiss are homogeneous to layered, plagioclase - two-pyroxene rocks with minor biotite and a quartz segregation banding. The basic gneisses appear to retain a granulite facies mineralogy in the lowlands around Atikonak Lake where other lithologies suggest amphibolite facies conditions. The granulite facies assemblages may be metastable and inherited from earlier, possibly more widespread, granulite facies metamorphism. The basic gneisses are intimately associated with tonalitic to granodioritic, concordant and discordant sheets and net veins which do not occur in the paragneiss sequence. Garnet ± biotite are common in these granitoid sheets and at metabasite/paragneiss contacts; an alternative ferromagnesian mineralogy in these sheets at granulite facies is orthopyroxene ± biotite. Rare, quartzite layers also occur with the metabasites. They are clean, medium grained, recrystallized, thin to medium bedded rocks with up to 10 percent diopside or garnet + magnetite ± biotite. The thinner bedded quartzites usually contain the diopside or have a calcareous matrix. A large boulder of interlayered quartzite, granulite facies metabasite and pink marble was found and is believed to have been locally derived. The rocks of unit 1d are believed to represent a basic volcanic - quartzite or chert - carbonate association, and the metasedimentary paragneiss to have a graywacke protolith.

Unit 2: Basic Plutonic Suite

Members of this suite range from noritic through gabbronoritic to gabbroic, and are dominated by leucocratic lithologies. They vary from massive, medium to very coarse grained, seriate intergranular rocks preserving primary or pseudomorphed igneous textures, to isotropic to foliated (rarely gneissic) fine to medium grained granoblastic metamorphic rocks with coarser grained sweats. In the first type, primary pyroxene phenocrysts and groundmass plates are abundant whereas plagioclase is usually recrystallized, but may contain rare relict cores. Olivine and biotite may be present and Fe-Ti oxides are abundant. Compositional variations are common but layering is rare. With increased recrystallization and deformation, these rocks grade into the metamorphic members of the suite in which they are locally preserved as strain augen. Olivine is absent in the recrystallized rocks, but biotite is more abundant and the clinopyroxene may be diopside rather than augite. These rocks are generally massive with weak pyroxene and plagioclase mineral fabrics, and they may contain coarser grained noritic or granitic material in irregular patches and net veins or as an incipient layering. A strong fabric is present in the granitic veins. Rare, folded layering in the basic plutonic rocks may represent an earlier metamorphic fabric or relict primary layering.

In the areas metamorphosed to amphibolite facies, there is partial replacement of the pyroxenes by hornblende and biotite. Corona textures were not noted in any of the basic plutonic suite lithologies (*cf.* unit 3, Nunn and Christopher, 1983).

Unit 3: Orthogneiss and Foliated Granitoid Rocks

Unit 3a consists of moderately to strongly foliated, weakly migmatitic, megacrystic granodiorite, adamellite and quartz monzonite with minor nonmegacrystic lithotypes. The megacrysts are up to 5 cm across and the groundmass is composed of recrystallized quartz, feldspar, biotite and magnetite. The megacrysts are usually partially rounded and variably replaced by polygonal microcline. A strongly deformed variety of this rock contains rounded and oval, medium to coarse grained (less than 1.5 cm across) K-feldspar relicts in a fine grained groundmass. The megacrystic rocks are weakly migmatitic and contain an incipient layering or patchy development of granitic melt which is in contrast to the less abundant nonmegacrystic rocks that are generally well layered.

Unit 3b consists of orthopyroxene-bearing varieties, chiefly farsundite (quartz monzonite to adamellite) and opdalite (granodiorite), and is closely associated with the eastern occurrences of the gabbronorite suite. These rocks of charnockitic affinity are weakly foliated and megacrystic, weathering to a rusty buff color. About half of the feldspar fraction consists of centimetric K-feldspar megacrysts in a matrix of medium grained, recrystallized plagioclase and quartz. Orthopyroxene, opaque oxides, and fine felted biotite possibly replacing orthopyroxene, comprise up to 10 percent of the rock.

Unit 4: Anorthosite Suite

This unit consists of massive anorthosite and noritic anorthosite (4a) with a northern (?marginal) anorthositic norite phase (4b). The plagioclase in both units is a dark gray or reddish color and varies from coarse to very coarse grained. The color index ranges from 5 to 20 in unit 4a and from 20 to 35 in unit 4b. The matrix is composed of orthopyroxene and Fe-Ti oxides ± olivine, and pyrite is a common accessory. The pyroxene and olivine are commonly partly or completely replaced by corona minerals. The overall texture appears intergranular to subophitic, but layering and igneous lamination observed in rocks to the south of the map area suggest that the body is of cumulate origin.

Parts of this unit have been strongly deformed and the plagioclase has recrystallized to form polygonal white aggregates with or without relicts of the gray and red feldspar. In the eastern part of the unit 4 outcrop area, the mafic minerals are recrystallized to fine grained, equigranular orthopyroxene, whereas farther west they are replaced by polygonal hornblende aggregates. Locally, the rocks become fine grained, flaggy white gneisses. Corona textures generally have been destroyed wherever deformation and recrystallization are well developed.

Unit 5: Diabase dikes

Diabase dikes are widespread and are most common in the western uplands. They are very variable in orientation and seem post-tectonic, although one dike was observed to contain a fabric. The dikes are fine grained and generally less than 50 cm wide; two coarser grained dikes, approximately 40 m and more than 100 m wide, are shown in map sheet 23A/9. The former is traceable for more than 6 km.

Mineralization

The intercalated metabasic volcanic rocks and paragneisses contain numerous rusty weathering zones whereas the paragneisses away from this association are not known to contain such zones. Malachite showings are present in all the major rock types in the northwestern part of the map area (23A/15) and may be associated with north trending ductile structures or lineaments, or the basic rocks (units 1d and 2). The granitoid, gabbroid and paragneiss units are all rich in magnetite and poor in sulfides. No gemstone quality laboradorite occurrences were found in the anorthositic suite, but these rocks contain abundant magnetite and disseminated pyrite, and similar anorthosites in nearby Quebec are a major source of titanium.

Lake sediment geochemistry is now available for the area (Geological Survey of Canada, 1982).

Structure and Metamorphism

The structural and metamorphic history of the area has been summarized in Table 1, and a structural and metamorphic facies map has been reproduced in Figure 3.

The oldest structures in the area are the migmatitic layering in the metasedimentary units (1a,b,c), and a quartz segregation fabric in the metabasic unit (1d) of the paragneisses. The former structure occurs in very rare inclusions of paragneiss within unit 3 and elsewhere is cut across by dikes of unit 2. Folding of the layering in the inclusions is not necessarily a record of polydeformation prior to inclusion (*cf.* Nunn and Christopher, 1983). However, the inclusions are evidence of a gneiss-forming event prior to the emplacement of the plutonic suites (units 2 and 3) in the Paleohelikian, and this event is assumed to be Hudsonian or early Paleohelikian (HPD) in age.

The deformation sequence is divided by the emplacement of units 2 and 3 in this map area. Regionally, either intrusion of unit 3 or the younger Labradorian events might be diachronous, or a part of unit 3 might be syntectonic, since there is such close agreement between the ages of emplacement of the North Pole Brook Intru-

Table 1: *Summary of structural and metamorphic events.* *

UNIT	EVENTS	FOLDING, FAULTING	FABRICS	MIGMATIZATION	METAMORPHIC GRADE
1	*Deposition*				
	Basic dykes				
	HPD_1	–	*HPS_1, Location fabric** in (1)*	*HPM_1, major*	*uA+*
	HPD_2	*HPF_2, rare isoclines in (1a)*	–		*?*
2	*Intrusion*				
3	*Intrusion*				
	LD_1	–	*LS_1, rare location fabric in (3)*	*LM_1, possible range in (1)*	*uA(1a, 1c), G(1b)*
	LD_2 - early	*LF_2, tight to isoclinal in (1, 3)*	*LS_2, major, mineral and shape fabrics in (1, 2, 3)*	*LM_2, minor + late to post-tectonic sweats*	*uA(1a,), G(1b, 1c)*
	- late	*Thrusting, possible range or regeneration*	*Mylonite, shear zones and straight belts*		*uA*
	*LD_3****	*LF_3, moderate to tight in (1)*	–	–	*A*
	Basic dykes			*2-mica and muscovite-bearing granite dykes*	*mA?*
	LD_4	*LF_4, open to tight, regional map scale*	–	–	*mA?*
				2-mica and muscovite-bearing granite dykes	*mA?*
4	*Intrusion*				
	GD_1, or LD_2 - late to pre-LD_4	*Major ductile shear zone*	*transposition in (1b), mineral fabric in (2, 3), mineral and shape fabrics in (4)*	–	*mA?*
	GD_2, or LD_4, or later	*Atikonak lineament*	–	–	*?*
	D	*Faulting*			*Gs*

* *Adapted from Nunn and Christopher, 1983. Numbers in parentheses refer to legend and text. A, amphibolite facies; u, upper; m, middle; G, granulite facies; Gs, greenschist facies; + denotes "or higher".*

** *Arrangement of fabric elements in layers (three dimensional).*

*** *This event is not equivalent to that labelled GD_3 in the table of Nunn and Christopher (1983); an equivalent of this event should be inserted between GD_3 and GD_4 of their table.*

sive Suite and ages of the peak metamorphism of the Labradorian events.

Structures that postdate the granitoid and gabbroid plutonic suites are assigned to the Labradorian deformation (LD). Early Labradorian deformation (LD_1) is represented by a major discordant migmatization in unit 1 and by a migmatitic layering in parts of unit 3. Its effect on units 2 and 4 is unknown. In order to account for the subsequently more rigid behavior of the paragneisses of subfacies 1b, we suggest that this domain was metamorphosed to granulite facies at LD_1 time, and thence behaved as a relatively dehydrated block, whereas the other paragneiss areas reached only upper amphibolite grade (*cf.* units 1b to 1a and 1c). However, we cannot exclude possibilities of older (HPD) or younger Labradorian ages of granulite facies metamorphism.

LD_2 was the peak metamorphic event of the Labradorian orogeny. Earlier migmatite or primary fabrics were tightly to isoclinally folded, major recrystallization occurred, and axial planar fabrics were developed in units 1, 2 and 3. Further migmatization was restricted to the formation of isolated axial-plane-parallel pegmatites and diatexites. Metamorphism reached upper amphibolite facies in the lowland regions and granulite facies in the areas underlain by subfacies 1b and 1c, the two upland portions of the map area. Late LD_2 events include the thrusting of the western upland granulite terrane into its present position overlying amphibolite facies paragneiss, and a posttectonic, static recrystallization which destroyed many of the LS_2 mineral fabrics. The eastern upland granulite block may also have been thrust into place at that time.

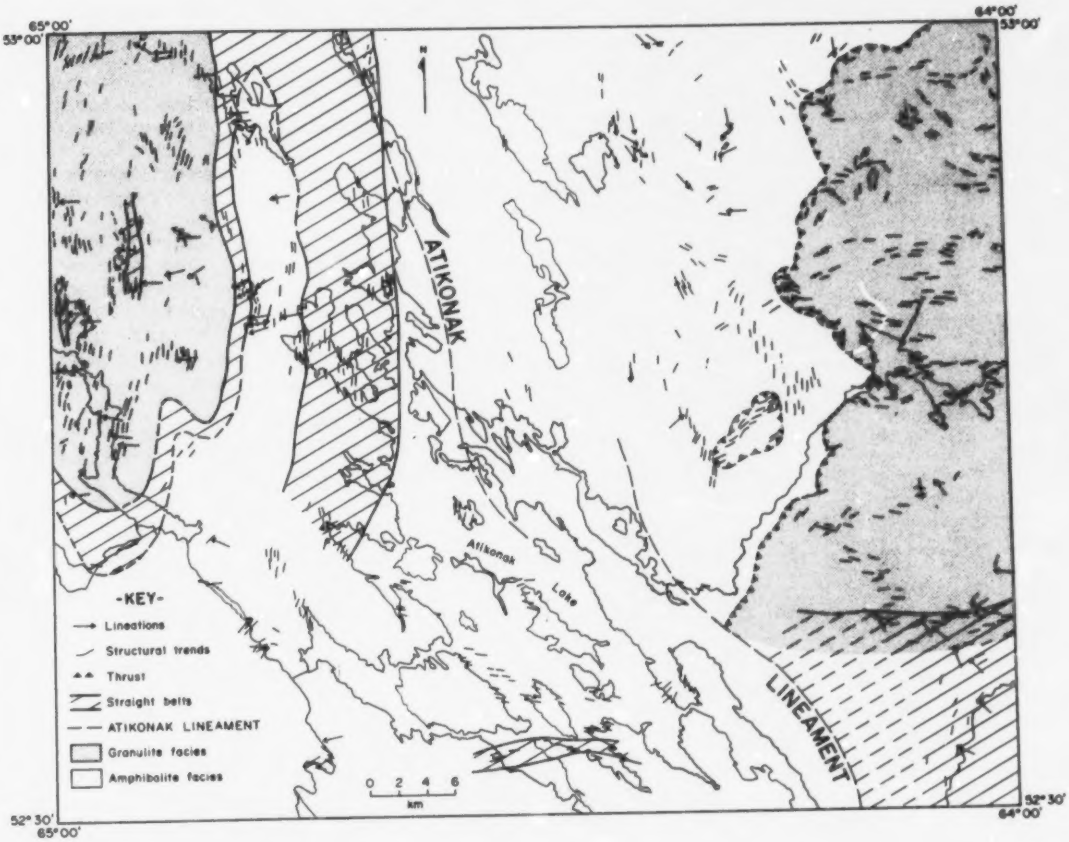

Figure 3: *Structural and metamorphic facies map.*

The mineral and migmatite fabrics were moderately to tightly folded during LD_3 and openly to tightly folded during LD_4. No new mineral fabrics were developed with these deformations.

LD_1, $_2$ and $_3$ structures have an overall easterly but variable strike in the eastern upland region of the map area, and the lineations are variable except along the southern margin of the granulite facies area where a high strain zone (late LD_2?) tightens all the earlier structures and the lineation becomes consistently steeply plunging to the north-northwest. In the other regions of the map area, these structures are oriented with a northerly strike controlled by the limbs of LD_4 folds. In the western uplands where the LD_4 deformation is tight, and apparently colinear with LD_2, the northerly strike is very consistent and the lineations are strong and moderately plunging to the west. Throughout the lowland regions, the structures are less regular and LD_4 hinge zones are common perturbations on the regional strike pattern. The lineation is still fairly consistently toward the west. Most of the lineations are more or less down-dip regardless of the strike of the LS_2 fabric.

The high strain zones and metamorphic facies boundaries are principally late LD_2 events. The one surrounding the eastern upland has not been seen except in the south where it appears to be truncated by the Atikonak lineament. There is, however, a strong discordance of fabric at the base of the small inferred klippe in the southern part of map sheet 23A/16. The western boundary is a transition zone marked by a number of straight belts. Fabrics within these straight belts may be glassy and submylonitic and are conformable with the "normal" LD_2 structures outside the shear zones, a feature that is also common north of the map area (Nunn and Christopher, 1983). The substitution of biotite-rich restites for the more common sillimanite - Fe-Ti oxide - biotite restite is best developed in these straight belts and is clearly related to deformation.

These high strain zone fabrics are also moderately to tightly folded by LD_4 folds in the western areas.

The LF_4 axial traces in the map area and related fold axes to the north and northeast (Figure 4) form a divergent fan in the less competent upper amphibolite facies gneisses around the northwestern corner of the eastern granulite terrane which appears to be acting as a rigid block. This fanning of the fold axes indicates that the eastern upland thrust block was in place at that time and that thrust-emplacement occurred at a time similar to that of the western granulite terrane (i.e. late LD_2).[*] The last generation of granitic intrusion consists of dikes of muscovite granite, commonly tourmaline-bearing, which were emplaced both before and after the LD_4 folding. The LD_4 folding is responsible for the regional map pattern.

Though the sequence of events from LD_2 to LD_4 apparently represents the waning stages of an orogenic cycle, there are no age constraints on post-LD_2 structures, and subsequent events might be Grenvillian.

In the southeastern part of the map area, a major shear zone occurs principally in the anorthositic rocks (unit 4). The zone strikes approximately 090°, dips steeply to the north and has a down-dip lineation. The sense of movement on the shear zone is not known.

The Atikonak lineament (Figure 3) is based primarily on aeromagnetic interpret-

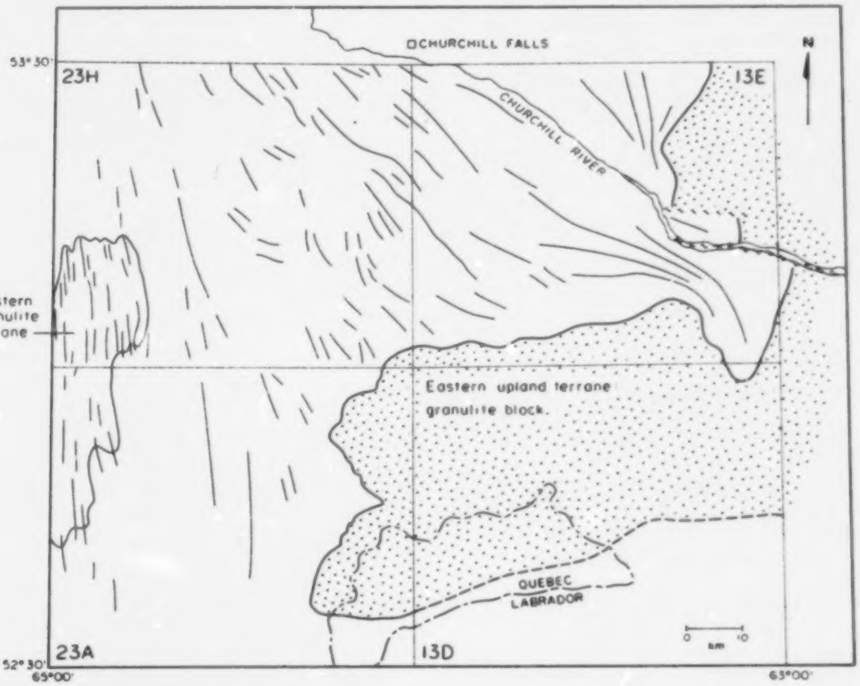

Figure 4: *Schematic representation of late fold traces, mostly LF_4 and equivalents, to show fanning of LD_4 structures around the eastern granulite facies block. Data from the present study (23A), and adapted from Nunn and Christopher, 1983 (23H), Thomas and Wood, 1983 (13E) and Thomas et al., 1984 (this volume) (13D).*

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[*] *In the Wabush area of western Labrador, 140 km to the west-northwest, northwesterly trending structures similar to, and possibly synchronous with, the LD_4 folds occurred late in a Grenvillian deformation sequence that was initially characterised by northwesterly directed thrusting (T. Rivers, 1983). The LD_4 folds, therefore, might be Grenvillian structures and the thrust-emplacement of the eastern upland terrane might be late Labradorian or early Grenvillian.*

ation. The feature truncates other trends on the aeromagnetic map (Geological Survey of Canada, 1978), appears to deflect the shear zone fabric in unit 4, and may have a sinistral displacement. The lineament may have reactivated older strain zones in the northern part of the map area. The post-unit 4 structures may be Labradorian or Grenvillian in age.

Summary

Field mapping undertaken during 1983, combined with recent geochronological results (Krogh, written communications, 1983) on the whole project area, suggests, in agreement with previous work, that:

(i) the paragneisses were derived from a slope or basinal sequence, probably largely of graywacke-shale composition, with minor intercalations of basic volcanic rocks and either quartzite or chert horizons. In previous work (e.g. Nunn and Christopher, 1983; Rivers and Nunn, 1983), this sequence has been tentatively proposed as an equivalent to the deeper water parts of the Labrador Trough succession, located 100 km northwest of the area. However, reconnaissance mapping conducted in 1983 indicates that these paragneisses and the metasediments of the Labrador Trough are probably separated by major thrusts, and it may be premature or invalid to correlate the two;

(ii) the paragneisses record a polyorogenic history with a preplutonic and a postplutonic component. The early component was probably pre-1670 Ma but is otherwise constrained only by the probable Aphebian age of the sedimentary protolith. Units 2 and 3 comprise the plutonic interval;

(iii) a major granitoid plutonic event probably occurred within the time interval 1670-1650 Ma, possibly in association with the intrusion of the gabbroid suite. Pregranitoid gabbroid suites are spatially and complexly associated with the granitoid rocks throughout the Trans-Labrador batholith (Emslie et al., 1978; Wardle and Britton, 1981; Nunn and Noel, 1982; Gower and Owen, in preparation).

However, contrary to previous work, it is concluded that:

(i) the main dynamothermal events in the area were mid-Paleohelikian (circa 1650 Ma), not Grenvillian, and are here termed the Labradorian orogeny;

(ii) the basic plutonic suite predates the granitoid plutonic suite and the correlation by Nunn and Christopher (1983) with the Shabogamo Intrusive Suite of western Labrador (Rivers, 1980) is probably no longer valid;

(iii) structures of apparent Grenville age consist of shear and thrust zones which in places separate huge tracts of older gneisses;

(iv) the Grenvillian metamorphic grade probably does not exceed lower amphibolite facies throughout the northern 120 km of the Grenville Province.

The structural history of the Labradorian orogeny is complex and its effects were heterogeneous. Because of this structural heterogeneity, separation of younger (post-LD_2) Labradorian from Grenvillian structures is locally difficult, and considerable uncertainty still exists regarding the effects of the Grenvillian Orogeny versus those of earlier events. The uncertainty is presently most marked for the anorthosite suite, since the ages of both the anorthosite suite and the structures in it are not known.

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GEOLOGY OF THE LAC GHYVELDE - LAC LONG AREA, GRENVILLE PROVINCE, LABRADOR AND QUEBEC

by

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Also in *Current Research*, Part A, Geological Survey of Canada, Paper 84-1A.

Abstract

Continuing studies of Precambrian granitoid and gneiss rocks belonging to the Grenville Structural Province in central and south-central Labrador yield evidence of a major Paleohelikian orogenic event. A crustal block in the northern part of the map area comprises mainly polydeformed, granulite facies, quartzofeldspathic paragneiss which contains the mineral assemblage hypersthene, sillimanite, quartz, K-feldspar, sapphirine, and can be traced continuously into equivalent gneiss of known Paleohelikian age. Several gabbronorite and charnockite bodies are also present in the southwest portion of this block.

Granulite facies tonalite to quartz tonalite gneiss having the mineral assemblage orthopyroxene, clinopyroxene, garnet, quartz and feldspar was intruded by a body of porphyritic granodiorite-granite, parts of which were subsequently tectonized to augen gneiss and banded orthogneiss. Together these two units define a distinct crustal block covering much of the southern part of the area. Anorthosite and related gabbronoritic to charnockitic rocks of unknown age intrude both granodiorite-granite of the southern block and gabbronorite-charnockite of the northern block. The two blocks are juxtaposed along a major structure, the Lac Long lineament, which traverses the entire map area from east to west and represents a fundamental lithotectonic break of Grenvillian(?) age.

Introduction

This report summarizes work carried out during the second year of a two-year project focusing on 1:100,000 scale mapping of crystalline rocks within the Grenville Structural Province of south-central Labrador. The project was initiated for three reasons: (1) to continue studies started in 1978, with particular emphasis on age and geological history of gneisses and granitoids in the Grenville Province; (2) to provide a much needed geological and geochemical data base for the sparsely mapped rocks of southern and central Labrador; and (3) to examine the bedrock mineral potential within this part of the Grenville Province.

The area covered encompasses N.T.S. 1:50,000 sheets 13D/11, 12, 13 and 14 contained within the boundaries 63°00' to 64°00' west longitude and 52°30' to 53°00' north latitude (Figure 1). It is a southward extension of the area mapped in 1982 and outlined in Thomas and Wood (1983). Part of the region north and west of Lac Long is in the province of Quebec and was mapped by N. Culshaw of the Geological Survey of Canada. The center of the map area is approximately 100 km south of the town of Churchill Falls, Labrador, and access is by float-equipped fixed wing aircraft or helicopter.

Relatively little previous work has been done in the region besides a 1:250,000 scale reconnaissance project carried out by Stevenson (1969) as well as some regional and detailed mapping by BRINEX (Pyke, 1956). Thomas and Wood (1983) provide references to previous work on adjacent map areas to the north.

Regional Setting

The Lac Ghyvelde - Lac Long area comprises a granulite grade terrain of paragneiss, tonalite gneiss, noritic and charnockitic igneous rocks along with their gneissose equivalents, metamorphosed granitoids and anorthosite. Beyond the map area, to the north and northwest, is a lowland terrain consisting of amphibolite

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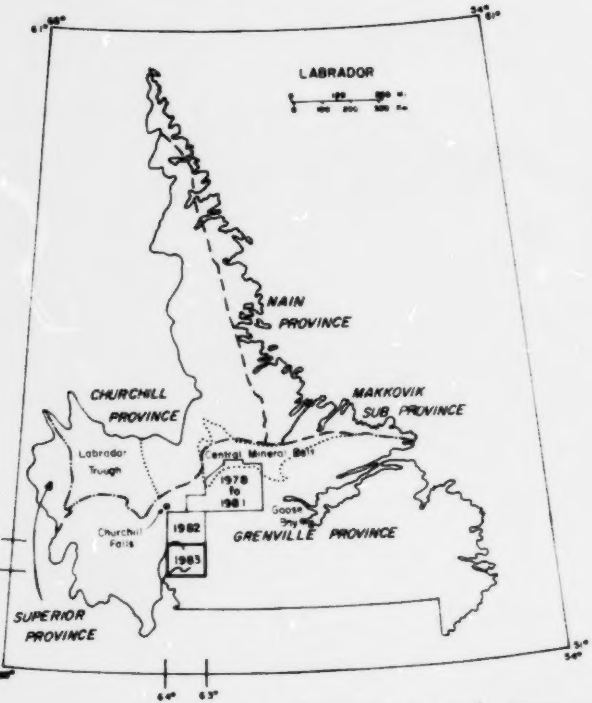


Figure 1: *Location of present and previous map areas in central and south-central Labrador (structural province divisions after Taylor, 1971).*

grade para- and orthogneisses as well as deformed granitoids. Within the northern half of the map area is a highland plateau underlain almost entirely by paragneiss which can be traced north through the southern part of the area mapped in 1982 by Thomas and Wood (1983), and thence continuously northeastward for almost 200 km into the Red Wine Mountains granulite massif. To the west, a poorly exposed, boggy lowland terrain is underlain by a mixed assemblage of paragneiss, anorthositic to gabbroic rocks and metabasics (Nunn et al., 1984).

To the southwest, a large body of anorthosite forms a range of high, barren hills. Part of this body becomes a narrow, northeasterly trending tongue which protrudes into the southwestern part of the map area. South and southeast of the map area, another poorly exposed lowland region contains a mixture of little metamorphosed gabbroic to granitic rocks as well as amphibolite grade paragneisses.

The region east of and directly adjacent to the map area can be divided into a highland plateau and extensively drift-covered lowlands. The plateau is a continuation of the one found in the northern part of the Lac Ghyvelde - Lac Long area, and is underlain by the same granulite grade paragneiss. The poorly exposed lowlands again comprise a mixed granitoid - amphibolite gneiss terrain, similar to that south of the map area.

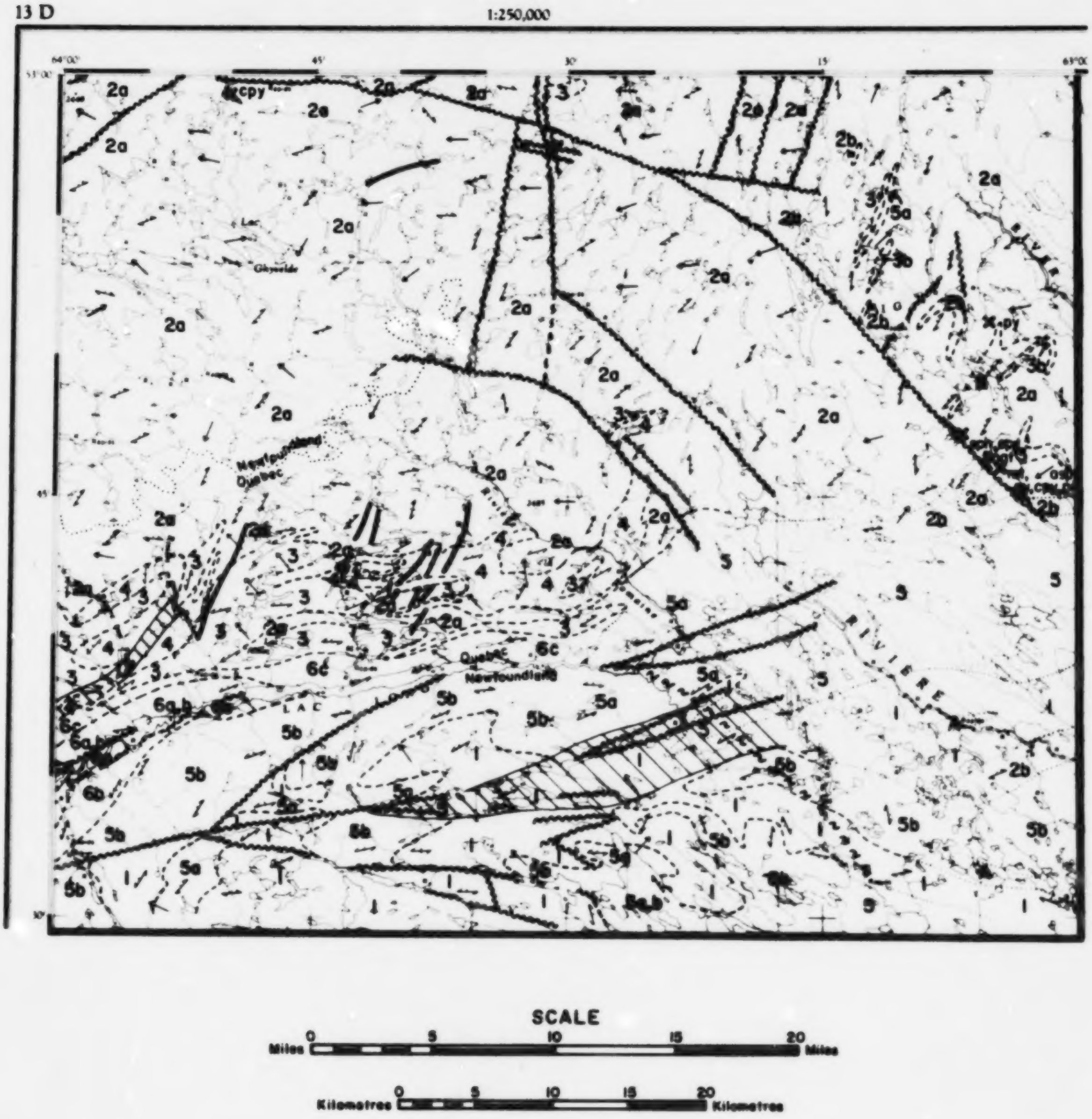
All rocks within this part of Labrador are polydeformed and underwent an extensive and complex geological history involving at least two distinct orogenic events at circa 1650 Ma and 1000 Ma.

General Geology

Six major and three minor lithological types have been defined (Figure 2). Granulite grade tonalite to quartz tonalite gneiss (unit 1) is presently thought to be the oldest unit in the area. The gneiss is confined to a rugged highland, which comprises the southern one-third of the map area, and does not outcrop anywhere north of Lac Long. This rock type has not been observed previously in central Labrador, and may represent ancient basement remnants.

The most widespread rock type is quartzofeldspathic paragneiss (unit 2), which is well exposed in a barren upland plateau comprising the entire northern half of the map area. The bulk of the gneiss underwent granulite facies metamorphism (unit 2a), with small local patches having only reached or else been retrograded to amphibolite grade (unit 2b). There are no compositional or structural differences between the two variants of gneiss; subdivision of the unit is based solely on mineralogical contrasts. Quartzofeldspathic paragneiss is correlated with Hope Lake gneiss of Emslie et al. (1978), Thomas (1981), and Thomas et al. (1981). Exposures of the gneiss can be traced continuously from the type locality at Hope Lake into the area of this study.

Strongly foliated to gneissic porphyritic granodiorite and granite (unit 5) outcrop extensively with tonalite gneiss in the southern highland, as well as in and along the southern edge of the fault-controlled glacial spillway within which Lac Long is situated. The granitoids along the spillway form a 5 to 15 km wide east trending belt which completely transects the map area, separating tonalite gneiss in the south from quartzofeldspathic gneiss, gabbroids and charnockitic granitoids in the north. Correlation of these granitoids with those of the North Pole Brook Intrusive Suite (see Thomas, 1981; Thomas et al., 1981) and its equivalents to the north of the map area (see Thomas and Wood, 1983) is being considered at this time.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Lac Ghyvelde
Newfoundland
Quebec
LAC LONG
RIVIERE
SCALE
Miles
0
5
10
15
20
Kilometres

Figure 2: *Geology of the Lac Ghyvelde - Lac Long area, Labrador and Quebec.*

LEGEND

GRENVILLIAN OROGENY

LATE HUDSONIAN TO PRE-ELSONIAN OROGENY

NEOHELIKIAN?

/ DIABASE.

AGE RELATIONSHIP AND AFFINITY UNCERTAIN

B DIORITE/QUARTZ DIORITE: Equigranular, moderately to strongly recrystallized, exhibiting relict igneous texture.

A GABBRONORITE: Fresh, ophitic igneous texture predominates (possible Shabogamo Gabbro)

PALEOHELIKIAN

6 ANORTHOSITE SUITE: 6a, Anorthosite, leucogabbro, monzogabbro; 6b, leuconorite/gabbronorite; 6c, charnockitic monzonite

PALEOHELIKIAN and/or EARLIER

5 GRANODIORITE/GRANITE: 5a, Strongly foliated to augen textured porphyritic granodiorite/granite; 5b, granodiorite/granite orthogneiss.

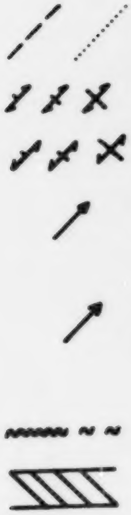
4 MEGACRYSTIC CHARNOCKITIC GRANITE

3 GABBRONORITE, includes several small pyroxene-rich ultramafic and ultramafic gneiss bodies (3b)

2 PARAGNEISS: 2a, Pink to grey, banded hypersthene-sillimanite-biotite ± sapphirine granulite grade quartzofeldspathic gneiss; 2b, pink to white, banded sillimanite-biotite ± muscovite ± garnet amphibolite grade quartzofeldspathic gneiss

1 TONALITE/QUARTZ TONALITE: Massive to gneissic, granulite grade

SYMBOLS



GEOLOGICAL BOUNDARY (approximate, assumed)

GNEISSIC BANDING-FOLIATION (inclined, vertical, horizontal)

FOLIATION (inclined, vertical, horizontal)

Plunging minor fold axes and mineral stretching lineations associated with earlier fold structures confined to the granulite grade paragneiss terrain

Plunging quartz ribbon, mineral stretching and intersection lineations associated with later fault structures, shearing, mylonitization and gneiss straightened zones along the Lac Long lineament

FAULT (defined, assumed)

SHEAR ZONE

× MINERAL OCCURRENCE py-pyrite, cpy-chalcopyrite, sph-sphalerite po-pyrrhotite, aspy-arsenopyrite, mt-magnetite.

A small recrystallized body of dioritic to quartz dioritic composition (unit B) is exposed near the east-central margin of the map area. It intrudes the surrounding paragneiss, but has no apparent relationship to the other granitoids, so that its age and origin are at present unknown.

Bodies of charnockitic granite (unit 4) occur with gabbronorite, as well as anorthosite and related rocks, in a 10 km wide tongue which protrudes into the west-central part of the area, along the contact zone between quartzofeldspathic gneiss of unit 2 and granitoid gneiss of unit 5. North and northwest of Lac Long, the granite both intrudes and is intertongued with gabbronorite and paragneiss. Due to similarities in lithology and geological relationships with host rocks, charnockitic granite is correlated with the monzodiorite / quartz monzonite unit of Emslie et al. (1978) as well as unit 3 of Thomas and Wood (1983).

Gabbronorite (unit 3) is present within granulite grade paragneiss as deformed and/or boudined intrusive bodies. All but two of these, located northeast of Lac Ghyvelde and near the east-central edge of the map area, are confined to the previously mentioned 10 km wide tongue. Due to similarities in mineralogy, several small, deformed, lenticular ultramafic and ultramafic gneiss bodies (unit 3b) of unknown age and origin are also included within the unit. Gabbronorite is correlated with unit 2 of Thomas and Wood (1983) and the gabbro, leuconorite, anorthosite unit of Emslie et al. (1978).

Two exposures of fresh, unmetamorphosed gabbronorite (unit A) occur in sand- and bog-covered ground in the southeastern part of the map area. These may belong to the circa 1380 Ma Shabogamo Intrusive Suite, but at present their origin is uncertain.

Anorthositic rocks (unit 6) in the southwest corner of the area have been subdivided into anorthosite and related gabbros (unit 6a), norites (unit 6b) and charnockitic monzonite (unit 6c). These rocks are part of a much larger anorthosite suite (presumably of Paleohelikian age?) which extends from the map area southwestward to Lac Fournier in eastern Quebec. They have a close spacial relationship with gabbronorite and charnockitic granite northwest of Lac Long, and are presently thought to be Paleohelikian in age.

Rare, late northeasterly trending diabase dikes cut quartzofeldspathic paragneiss, gabbroids and granitoids north of Lac Long. Their absolute age is unknown, but they are not strongly tectonized and may be late syn- or post-tectonic intrusives associated with the Grenvillian Orogeny.

Rocks within the Lac Ghyvelde - Lac Long area underwent two distinct orogenies. An earlier high grade event resulted in extensive complex folding accompanied by up to granulite grade metamorphism. A later, lower grade event is responsible for further tectonism, including folding and ductile and brittle faulting.

Tonalite - Quartz Tonalite Gneiss (Unit 1)

Rocks belonging to this unit are predominantly gneissic in character, although massive homogeneous zones of greater than outcrop scale were observed. Tonalite gneiss weathers gray to buff-white, is gray-green on fresh surface and banded in an irregular discontinuous manner. It consists of approximately 40% plagioclase, 30% pyroxene (augite and hypersthene), less than 10% quartz and garnet ± magnetite ± biotite ± minor hornblende. The rock exhibits an equigranular polygonal granoblastic texture with an average grain size of 1 to 2 mm. Garnet occurs both as subhedral to anhedral porphyroblasts or crystal aggregates up to 2 cm and as fine grained polygonal groundmass crystals. The gneiss is also characterized by particularly plagioclase-garnet-rich zones, containing abundant coarse aggregates of subhedral pyroxene crystals, possibly representative of meta-anorthositic rocks. Rounded garnet porphyroblasts ranging in size up to 10 or 12 cm are common to these meta-anorthositic rocks. Numerous relict mafic or ultramafic dikes and boudins, now consisting almost entirely of polygonal aggregates of hornblende and/or pyroxene, are present throughout the tonalite unit. Extensive reaction rims and bleached zones in the host tonalite occur at the rims of the dike relicts.

These dikes have been folded, flattened and boudinaged. Even where the tonalite is massive, the selvedge zones at their margins show complex fold interference patterns, indicating that the unit underwent pervasive deformation. In addition, cataclasis and shearing occurs sporadically along contact zones between tonalite and gneissic granodiorite of unit 5.

The mineralogy, nature and partly massive character of the tonalite gneiss suggest an igneous protolith. The gneiss has apparently had a complicated structural-metamorphic history, and its protolith may have been as old as Archean (?).

Paragneiss (Unit 2)

Granulite grade quartzofeldspathic paragneiss (unit 2a) is rusty pink to buff, with an average grain size of 1 to 4 mm, dense and extremely resistant to weathering. It is well banded, with prismatic to fibrous sillimanite, fine grained hypersthene, magnetite, minor biotite and rare sapphirine confined to melanocratic layers which pinch and swell, imparting an anastomosed appearance to the rock. Melanocratic bands vary in width up to 2 cm and commonly contain lenticular clots of densely packed aggregates of fibrolitic sillimanite, pyroxene and magnetite. Leucosome bands consist of very dense, fine to medium grained granoblastic polygonal aggregates of quartz, K-feldspar and plagioclase. These bands are tightly folded; they pinch and swell, and may be up to 5 cm wide. Black pseudotachylyte lenticles and discontinuous layers up to 1 cm wide are commonly found parallel or subparallel to melanocratic bands; pseudotachylyte veinlets in the same size range also crosscut leucosome bands. Abundant evidence of partial melting is present in the granulite paragneiss, with both layer-parallel and crosscutting quartz-feldspar sweats being common. This melting took place under dry conditions at high temperatures as evidenced by subhedral to euhedral hypersthene crystals up to 1 cm long in some of the sweats.

Amphibolite grade quartzofeldspathic paragneiss (unit 2b) is relatively uncommon, being confined to several small (less than 5 km), narrow lenses in granulite grade paragneiss and two narrow belts in tonalite - granitoid gneiss within the eastern part of the map area. It is buff-white to pink on weathered surface and consists of quartz, K-feldspar, plagioclase, sillimanite, biotite, muscovite, garnet and magnetite-ilmenite. Metamorphic differentiation is well developed with mafic minerals segregated into bands up to 0.5 cm wide, separated by 2 to 3 cm wide quartz-feldspar bands. Due to the abundance of biotite and muscovite, amphibolite grade paragneiss is less dense and more fissile than its granulite grade counterpart. Granoblastic polygonal texture predominates within the quartz-feldspar bands and is in most places medium grained.

Paragneiss is extensively tectonized, with granulite facies gneiss in particular exhibiting complex minor fold patterns including mushroom and dome and basin structures plus centimetre scale, tight, isoclinal, chevron and hook folds. The small scale fold patterns in the gneiss are identical in style to and mimic the regional scale structures. As previously mentioned (Thomas and Wood, 1983), mineralogy and chemical composition of this paragneiss unit suggest derivation from a sedimentary protolith. A U-Pb age on zircon (Krogh, written communication, 1983) from a sample of granulite grade paragneiss collected during the course of the Thomas and Wood (1983) study, although discordant, has yielded a lower intercept age of 1676 Ma. This date probably represents the age of granulite grade metamorphism of the gneiss and therefore gives a minimum age for deposition of the protolith.

Gabbronorite (Unit 3)

The bulk of the gabbronorite unit comprises norite, two-pyroxene gabbro and two-pyroxene metagabbroic gneiss to metabasite. Additional but less voluminous associated lithotypes included within this unit are noritic gneiss, pyroxene-magnetite gabbro, pyroxene-olivine gabbro, ultramafics and ultramafic gneiss.

Norite is generally massive, and ranges from a medium grained variety with well developed subophitic texture, to a rock with cumulophyric orthopyroxene. These may reach sizes of 5 cm and be spectacularly kinked. Patches of coarse gabbroic pegmatite are also commonly found in norite. Plagioclase and orthopyroxene are subequal, with Fe-Ti oxides as accessories. Although primary igneous textures are discernible in this rock, plagioclase may be partly or wholly recrystallized into polygonal aggregates.

Two-pyroxene gabbro is medium grained and equigranular, with plagioclase partly recrystallized. With increased orthopyroxene content, this rock grades into norite.

Two-pyroxene metagabbroic gneiss / metabasite is the most common of the gabbroic rocks. In general it is uniform, massive and exhibits a very fine grained, equigranular, polygonal, granoblastic metamorphic texture. In some localities there is a sparsely developed granitic veining which on erosion surfaces appears to be smeared out into the regional stretching direction. Also present are charnockitic granite dikes.

Noritic gneiss is derived from the norite and is found interspersed with gabbroic gneiss. It is equigranular, medium to fine grained with a polygonal metamorphic texture. Compositional heterogeneities locally form a discontinuous layering, in some places deformed into intrafolial isoclinal folds.

Pyroxene-magnetite gabbro is found only in association with norites along the northern margin of the aforementioned 10 km wide tongue, and consists of medium to fine grained equigranular rocks in which Fe-Ti oxides are of greater or equal abundance to clinopyroxene.

Pyroxene-olivine gabbro underlies several small hills to the west of the lower reaches of Riviere aux Brochets. It is a uniform massive rock of high color index, containing medium to coarse pyroxene and olivine(?).

Rocks within the ultramafic and ultramafic gneiss bodies (unit 3b) are similar in character to the gabbronoritic rocks, but are composed almost completely of pyroxene with little or no plagioclase.

The lithotypes in the gabbronorite unit are correlated with identical rocks found in the Red Wine Mountains, northeast of the Lac Ghyvelde - Lac Long area by Emslie et al. (1978) and Thomas et al. (1981).

Megacrystic Charnockitic Granite (Unit 4)

Charnockitic granite is a weakly foliated megacrystic rock which weathers a rusty buff color. Large (up to 4 cm) unrecrystallized K-feldspar megacrysts are set in a matrix of medium grained plagioclase. Quartz content averages between 15 and 20%, but may be as high as 30%. Mafic minerals, which comprise no more than 10% of the rock, include orthopyroxene, Fe-Ti oxides and a fine felted biotite which is thought to have replaced orthopyroxene. Non-megacrystic granite, as well as pink and gray amphibolite facies metagranitoids, are found locally within charnockitic granite. The amphibolite facies granitoids exhibit a strong LS fabric associated with the development of a straight belt north and northeast of Lac Long which is discussed in more detail later.

Granodiorite - Granite (Unit 5)

Rocks of granodioritic to granitic composition have a much greater areal extent than the charnockitic granitoids, with two textural varieties evident. Porphyritic granodiorite to granite (unit 5a) is strongly foliated, and commonly, though not everywhere, phenocrysts are deformed into lenticular augen. Well developed porphyritic texture is preserved within these rocks south of both the east and west ends of Lac Long. Unit 5a rocks consist of abundant phenocrysts of microcline ranging in size from 2 to 4 cm, set in a medium grained groundmass of quartz, plagioclase, orthoclase, biotite, hornblende and minor garnet. Extremely mafic-deficient zones may be found throughout this unit. With progressive deformation, partial groundmass recrystallization and stretching of feldspar phenocrysts into lenticular augen of preferred shape orientation occurred. In the most highly deformed rocks, total recrystallization took place, resulting in the formation of orthogneiss (unit 5b) in which feldspar phenocrysts were either obliterated or combined with groundmass quartz to form quartzofeldspathic bands. Granodiorite - granite orthogneiss consists of quartz, plagioclase, orthoclase, hornblende, ubiquitous red garnet and minor amounts of biotite. Igneous texture is completely altered to medium to coarse granoblastic polygonal texture.

The granitoid rocks of unit 5 are found as dikes in unit 1 tonalite gneiss south of Lac Long. Their relationship to quartzofeldspathic paragneiss of unit 2 is unknown as no contacts were observed between the two rock types.

Anorthosite Suite (Unit 6)

Anorthosite, leucogabbro and monzogabbro (unit 6a) constitute approximately one-third of the mass of the anorthosite suite which protrudes into the map area. These rocks are massive to foliated, locally extremely flaggy and very coarse grained. The main mineral constituent is plagioclase, usually partially or wholly recrystallized to a fine, white equigranular aggregate. Coarse (1 to 10 cm) reddish brown phenocrysts of iron-stained plagioclase are confined to monzogabbro. Mafic minerals orthopyroxene, clinopyroxene and Fe-Ti oxides, ranging in size up to 15 cm, commonly form less than 20% of the rock and usually exhibit subophitic texture with the pyroxene being coronitic. Rarely, deformed and kinked pyroxene and Fe-Ti oxide crystals in excess of 0.5 m have been observed in pegmatitic zones within some of the more leucocratic rocks.

Leuconorite and gabbronorite (unit 6b) occur along the northwest shore of Lac Long as well as west and southwest of the lake. They are igneous textured rocks that vary in weathered appearance from black to a rusty cream color. Leuconorite is coarse, leucocratic and contains 20 to 30% subequal Fe-Ti oxides and orthopyroxene. Its texture is subophitic, with the two mafic minerals being commonly segregated into a crude layering, and locally the rock being strongly deformed and recrystallized. Gabbronorite is medium grained and consists of 30 to 50% orthopyroxene, clinopyroxene and Fe-Ti oxides in a buff-white to gray plagioclase groundmass. Plagioclase laths show varying degrees of recrystallization.

Charnockitic monzonite (unit 6c) is characterized by large K-feldspar megacrysts and an abundance of Fe-Ti oxides. As a consequence of the high oxide content, the rock has a very rusty appearance and a deeply weathered, friable nature. Quartz was not found in hand sample, and the freshest feldspar megacrysts have a greenish hue suggesting charnockitic mineralogy.

Gabbronorite (Unit A)

This lithology is similar in mineralogy to the other gabbronoritic rocks but differs in two respects: (1) grain size is generally finer, and (2) igneous texture is extremely fresh with no recrystallization of plagioclase or mafic minerals apparent in the two small exposures examined.

Diorite - Quartz Diorite (Unit B)

Diorite to quartz diorite is minor in occurrence and consists of medium grained recrystallized quartz, plagioclase, hornblende, biotite and rare garnet. Although it contains relicts of the "salt and pepper" igneous texture common to diorites, the rock is thoroughly overprinted with a polygonal granoblastic texture. Patchy zones appear to approach gabbroic composition. This rock may correlate with unit 6 of Thomas and Wood (1983).

Structure

Structural data support the division into two major crustal blocks, north and south of an east-west line passing through the center of the Lac Ghyvelde - Lac Long map area (Figure 3). This line is drawn along the northern edge of a locus of faults and shear zones in the vicinity of Lac Long, informally referred to as the Lac Long lineament. The northern crustal block can be further subdivided, on the basis of changes in structural trends and fold geometry, into eastern and western parts. In this way the map area is conveniently partitioned into three domains, within each of which the style and orientation of structures is internally consistent (Figure 3). There is evidence on the scale of mapping for at least three major deformation events involving folding and for three fault sets. No attempt is made to correlate faults with deformation responsible for folding.

The Lac Long northeast domain is characterized by isoclinal folds overturned to the southeast, of which the axial planes dip steeply to the northwest. A lower hemisphere stereographic projection (Figure 3) indicates that gneissic layering and foliation, coplanar with these axial planes, strike northeast and dip predominantly northwest. F_1, F_2, and F_3 fold axes plunge at moderate angles to the southwest, F_1 and F_2 being for the most part coaxial.

Although folds within the Lac Long northwest domain do not differ in style significantly from those in the northeast domain (i.e. 3 periods of deformation with refolding of earlier folds), some differences in geometry occur. F_1 and F_2 folds are isoclinal: however F_3 folds are open. F_1 and F_2 axial planes coincident with the orientation of gneissic layering and foliation dip steeply north-northwest and south-southeast (Figure 3) on either side of vertical F_3 axial planes which strike east-northeast. There is a significant rotation of these planes with respect to their counterparts from the northeast domain, into a more westerly trend. F_1 and F_2 minor fold axes in this domain retain moderate plunges but their trends are also rotated into a predominantly westerly orientation. Note in Figure 3 that a small percentage of lineations including F_1 and F_2 minor fold axes plunge to the east.

The Lac Long south domain is characterized by isoclinal folds overturned to the south. Axial planes trend east-northeast to east and dip north-northwest. Lower hemisphere stereographic projection of gneissic banding and foliation planes indicates a northeasterly to east-northeasterly trend and steep northwest dips, with development of a fairly intense maximum (Figure 3). F_1, F_2 and F_3 minor fold axes and associated lineations are rare, but those observed suggest a westerly plunge. Most lineations present in this domain represent mineral stretching and quartz ribbons associated with the formation of the Lac Long lineament. These have moderate northwest plunges that cluster into a strong maximum (Figure 3) which contrasts sharply with that of Figure 42.7 of Thomas and Wood (1983) for rocks north of the Lac Long northern domains.

The oldest faults trend north-south and are in rocks belonging to the northeast and northwest Lac Long domains. These are terminated by arcuate, southeasterly trending faults which exhibit some degree of left-lateral offset movement and could not be traced across the Lac Long lineament. The most recent faulting recognized occurs in association with the Lac Long lineament. This is a major structure that transects the map area from east to west, and has associated with it faults, shear zones and a strong aeromagnetic expression. Faults within the southern Lac Long domain are either parallel to or occur as subparallel splays off of the lineament.

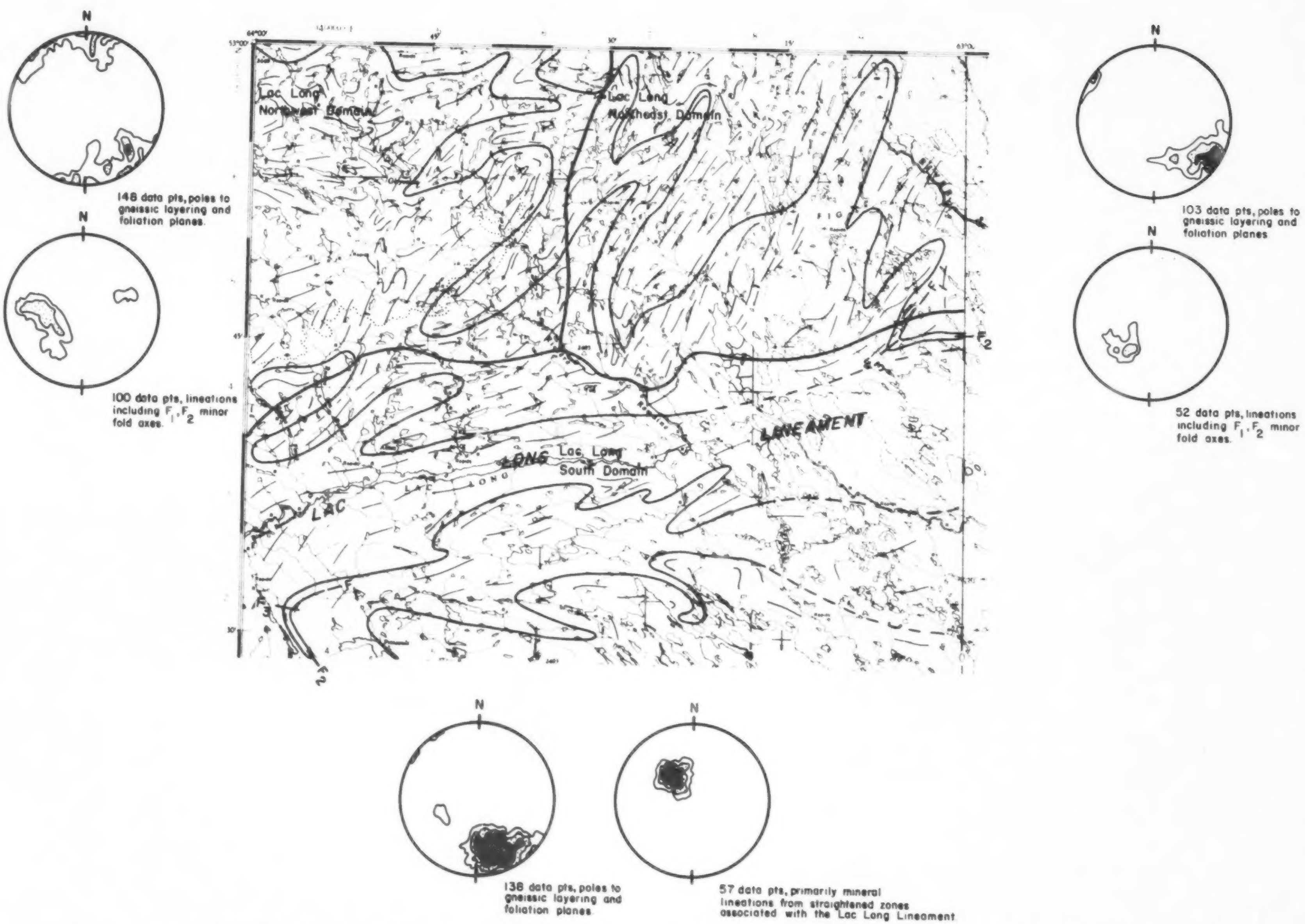

N
148 data pts, poles to gneissic layering and foliation planes.
N
100 data pts, lineations including F_1, F_2 minor fold axes.
Lac Long Northwest Domain
Lac Long Northeast Domain
Lac Long South Domain
LAC
LONG
LINEAMENT
F_2
F_2
F_3
64°00'
45'
30'
15'
63°00'
53°00'
45'
30'
N
103 data pts, poles to gneissic layering and foliation planes
N
52 data pts, lineations including F_1, F_2 minor fold axes.
N
138 data pts, poles to gneissic layering and foliation planes.
N
57 data pts, primarily mineral lineations from straightened zones associated with the Lac Long Lineament

Figure 3: *Bedrock structural trends within the three domains of the Lac Ghyvelde - Lac Long map area; stereonet contour intervals 3, 6, 9 percent of points per 1 percent area of the net.*

Structures in the northern Lac Long domains are confined to quartzofeldspathic gneiss of known 1600-1700 Ma age. Structures within the Lac Long south domain occur in widely differing lithologies of unknown age. The contrasts in both lithology and structural trends between the northern and southern crustal blocks suggest that different deformational events are represented. This conclusion is supported by the presence of a straightened belt within the northwest part of the Lac Long lineament, containing strongly developed LS fabrics which postdate those in the northern block, and transposed and flattened quartzofeldspathic granulite grade gneiss. It is suggested that structures within the northern crustal block are part of an old, circa 1650 Ma, orogeny and those in the southern block represent an even older orogeny, a second pulse of the 1650 event, or a younger (Grenvillian?) orogenic event. Geochronological study of the tonalite gneiss should solve this problem.

Metamorphism

With the exception of scattered areas of the quartzofeldspathic paragneiss, local zones in charnockitic granite, diorite - quartz diorite (unit 8) and granodiorite-granite (unit 5), all rocks within the Lac Ghyvelde - Lac Long region have stable metamorphic mineral assemblages characteristic of the granulite facies.

The K-feldspar - orthopyroxene - sillimanite ± sapphirine assemblage in quartzofeldspathic paragneiss of unit 2 requires formation under dry conditions at high temperatures and pressures, as does the plagioclase - pyroxene - garnet - magnetite assemblage of the unit 1 tonalite gneiss.

Anorthositic, gabbronoritic and charnockitic rocks may have been emplaced in their host rocks during a regional granulite facies event as evidenced by their stable high grade mineralogy and degrees of polygonal recrystallization. The grade of the granodioritic and dioritic units is difficult to ascertain due to a lack of suitable index minerals; however, the presence of hornblende, biotite and ubiquitous garnet as well as relict igneous texture suggest that they reached a metamorphic grade of no higher than amphibolite. It is possible that granulite facies metamorphism in the Lac Long south domain was overprinted by no greater than amphibolite facies metamorphism accompanying the younger orogenic event thought to have affected that domain. If so, this metamorphism may have caused only patchy amphibolite retrogression of the rocks north of the Lac Long lineament.

Economic Geology

Sparse sulfide mineralization is found in bedrock and float mainly in the northeast part of the map area. Pyrite and magnetite with minor chalcopyrite, arsenopyrite and pyrrhotite occur in a narrow local lens of possible metamorphosed iron formation in granulite grade quartzofeldspathic paragneiss. A 20 m wide gossan within the same paragneiss unit close to a small body of gabbronorite contains pyrite mineralization.

Chalcopyrite-, sphalerite(?)- and pyrite-bearing float is also found in the general region of the bedrock mineralization, but it is emphasized that the source of this float could be distant since glaciation from the northeast was extensive. A small occurrence consisting of stringers of an unknown Cu-bearing mineral is located in paragneiss 5 km north of Lac Ghyvelde, but was not examined during the course of this study.

Fe-Ti oxides are abundant in the anorthosite suite rocks examined previously by BRINEX for Ti potential. Well sorted, almost pure magnetite-ilmenite sand occurs on a small beach midway along the north shore of Lac Long suggesting that this body of rocks warrants additional study.

Discussion

From the outset, in 1978, of recent studies into the nature and extent of the Grenvillian Orogeny in south-central Labrador, a number of unexpected findings have ensued. Before that time, it was concluded that amphibolite to granulite grade metamorphic events recorded in large expanses of paragneiss and orthogneiss within the region were of Grenvillian age. Similarly, it was thought that most if not all of the major structural deformation was due to the Grenvillian Orogeny.

Grenvillian structural effects have been documented in the Seal Lake Group along with subgreenschist to greenschist facies metamorphism, as far as 230 km north of the present map area. In addition there are numerous examples of circa 1000 Ma potassium-argon dates from the Seal Lake Group south into the region of this study. During the recent studies, however, a number of uranium-lead (Krogh, written communication, 1983) and rubidium-strontium (Fryer, 1983) ages of circa 1600-1700 Ma have been obtained for high grade crystalline rocks from well within the present boundary of the Grenville Province (Figure 4). These record metamorphic events in both para- and orthogneisses varying in grade from amphibolite to granulite, as well as

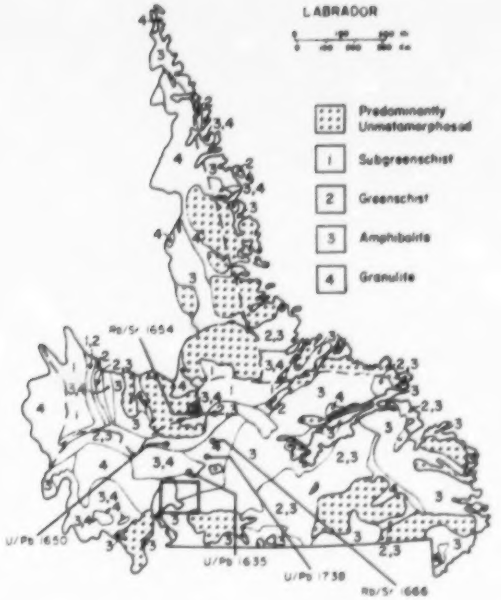


Figure 4: *Regional metamorphic zones in Labrador, with recent geochronological data superimposed (modified from Fraser and Heywood, 1978).*

several cooling ages of little deformed granitoids. Rubidium-strontium isochrons which yield these dates are largely undisturbed. Uranium-lead results giving these dates are nearly concordant, with minor lead loss attributable to a circa 1000 Ma event. The dates therefore suggest that many of the presumed high grade Grenvillian gneisses in this part of Labrador belong to a much older crystalline terrain which underwent a Grenvillian metamorphic event of much lower intensity than previously assumed. In summary, the geochronological, structural and metamorphic data as well as to some extent contrasting lithologies, record a previously unsuspected intense Paleohelikian orogenic event at circa 1600-1700 Ma which affected the rocks in central and south-central Labrador. This event has been informally termed the Labradorian Orogeny by Nunn et al., 1984.

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GEOLOGY OF THE NORTH WEST RIVER AREA

by

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Abstract

The North West River area is located within the northern part of the Grenville Province 100 km south of the Grenville Front.

The area consists of two major geological components: a pre-Grenville granitoid - metasedimentary gneiss complex believed to have experienced a high grade metamorphic event circa 1650 Ma, and a younger allochthonous gabbro-anorthosite suite of unknown age which was translated northwards as the Cape Caribou River allochthon during the Grenville Orogeny.

The granitoid and metasedimentary gneiss complex is transected by a major northeast trending Grenvillian thrust which to the northeast forms the boundary between Lake Melville and Groswater Bay terranes. In the map area the thrust separates local areas of granulite grade metamorphism in the south from kyanite-, sillimanite- and epidote-bearing assemblages to the north.

Development of the Cape Caribou River allochthon was associated with intense deformation and recrystallisation of the basal part of the gabbro-anorthosite suite under largely anhydrous conditions. The basal part of the allochthon comprises an enigmatic unit of mylonitic amphibolite - mafic granulite interlayered with mylonitic orthopyroxene-bearing granite. This may represent the basal contact region of the gabbro-anorthosite suite.

Following the Grenville Orogeny the area was stablized, uplifted and then subjected to a period of late Precambrian-early Paleozoic extensional tectonism associated with development of the Lake Melville graben system. It is speculated that parts of the Lake Melville lowlands near North West River may form part of the graben and be floored at depth by late Precambrian-early Paleozoic sedimentary rocks.

Following deglaciation of the area in the Quaternary, the area around North West River and Lake Melville was covered with extensive glaciofluvial outwash and estuarine deposits of till, sand and clay.

Mineralisation in the area is restricted to minor magnetite, illmenite and fluorite showings in the anorthosite, and pegmatite-hosted ilmenite in metasedimentary gneiss.

Introduction

The map area is located in eastern Labrador at the western end of Lake Melville (Figure 1), and includes the community of North West River which is connected by road to the town of Goose Bay 34 km to the south.

The only previous work in the area has been reconnaissance mapping by the British Newfoundland Exploration Company (BRINEX, 1954) and the regional mapping of Stevenson (1969) for the Geological Survey of Canada.

The present project was initiated to link the Newfoundland Department of Mines and Energy 1:100,000 scale mapping by Ryan et al. (1981, 1982) to the west with that by Erdmer (1983) to the north. The area to the south has yet to be mapped at 1:100,000 scale.

General Geology

The map area lies within the Grenville Structural Province of eastern Labrador and is situated 100 km south of the northern limit of Grenvillian deformation as defined by Gower et al. (1980) (Figure 1 inset).

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The area is divisible into two major geological components. A pre-Grenville gneiss complex, believed to have undergone high grade metamorphism circa 1650 Ma, underlies the northeastern half of the area, and has been overthrust from the south by a younger allochthon consisting of amphibolite, gabbro and anorthosite (Figures 1 and 2).

The pre-Grenville complex consists of minor bands of kyanite bearing metasedimentary gneisses (Unit 1) interspersed within a terrane of heterogeneous granitoid gneiss (Unit 2). Following high grade metamorphism at circa 1650 Ma, these were intruded by minor bodies of younger granite (Units 3 and 4).

The allochthon, initially recognized by Ryan et al. (1981) and named the Cape Caribou River allochthon (Figure 1), consists of a basal unit of highly mylonitized and interlayered amphibolite - mafic granulite and white pyroxene-bearing granite. This is overlain by a gabbro-anorthosite suite comprising a lower unit of well layered amphibolite (Unit 6a) followed upward by more massive metagabbro and leucogabbro (Unit 6b), and finally by massive coarse grained anorthosite (Unit 7).

The eastern part of the map area bordering Lake Melville is a low lying plain (Lake Melville lowlands) formed by Pleistocene sand, clay and till deposits. These are probably largely of fluvioglacial outwash origin but the presence of numerous relict strand lines around both Lake Melville and North West River suggests reworking in estuarine or lacustrine environments during postglacial uplift of the Lake Melville region.

It is speculated that much of this lowland area is a down faulted block forming part of the late Precambrian - early Paleozoic Lake Melville graben system. The possibility exists, therefore, that the lowlands are underlain by late Precambrian - early Paleozoic sedimentary rocks.

Unit 1: Kyanite-sillimanite-bearing Metasedimentary Gneisses

These occur principally in a narrow 1 to 2 km wide belt in the northwestern part of the map area (Figure 2) where they separate in part the Cape Caribou River allochthon from the granitoid gneisses of Unit 2. This belt may be connected through a drift-covered area with an outcrop area near the northern margin of the map area. This latter area forms part of a north trending belt of metasedimentary gneiss extending into the area mapped by Erdmer (1983, *his Unit 1a*). A small sliver of gneiss was also been caught up and severely mylonitized within the northeast trending overthrust zone.

The gneisses are generally pink or pale gray in outcrop, the two varieties usually being interbanded. They are strongly migmatitic (Plate 1), with over 25% melt fraction, and display an intricate pattern of small scale isoclinal folds characterized by numerous second and third order parasitic folds. The gneisses also typically possess a fine centimetric scale gneissic banding within which bands of quartz + K-feldspar + plagioclase leucosome alternate with darker melanosome bands of aluminosilicate + muscovite + biotite + magnetite + garnet + quartz + feldspar composition.

Plate 1: ***Migmatitic, kyanite-bearing metasedimentary gneisses, Unit 1.***

The metasedimentary gneisses also contain sparse pods and boudinaged bands of garnet + biotite amphibolite which are interpreted as relict pretectonic dikes. Larger bodies of garnetiferous amphibolite also occur within the metasedimentary gneisses and may be genetically related to the dikes. Kyanite is the predominant aluminosilicate polymorph and usually occurs in the assemblage kyanite + K-feldspar + quartz + plagioclase + biotite + magnetite + garnet. It is usually visible on foliation surfaces as 0.5 to 1 mm pale green prismatic grains or grain aggregates.

At the southern end of the paragneiss belt, and in the small sliver located along

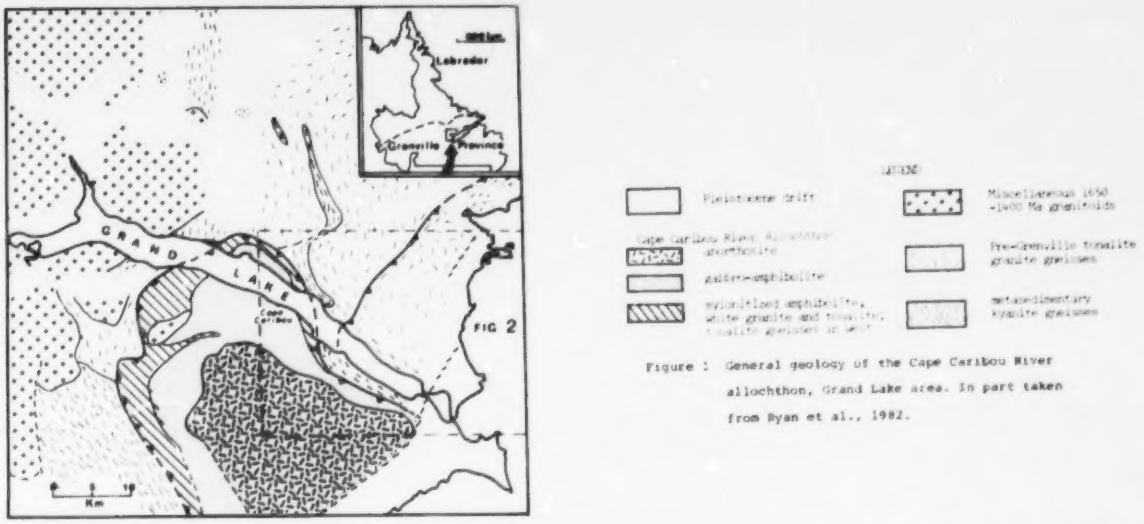
Labrador
Grenville Province
GRAND LAKE
Cape Caribou
FIG 2
Km
LEGEND
Pleistocene drift
Cape Caribou River Allochthon
anorthosite
gabbro-amphibolite
mylonitized amphibolite, white granite and tonalite, tonalite gneisses in west
Miscellaneous 1650 -1400 Ma granitoids
Pre-Grenville tonalite granite gneisses
metasedimentary kyanite gneisses

Figure 1 General geology of the Cape Caribou River allochthon, Grand Lake area. In part taken from Ryan et al., 1982.

Figure 1: *General geology of the Cape Caribou River allochthon, Grand Lake area. In part taken from Ryan et al., 1982.*

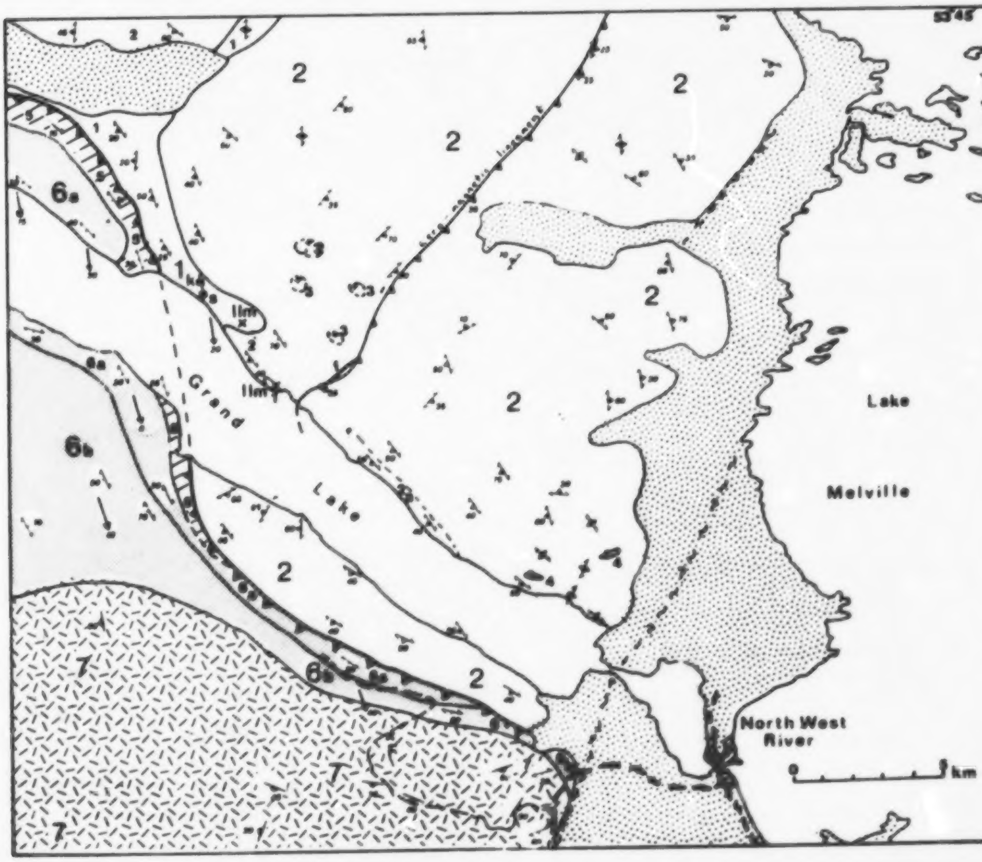
2
6a
6b
7
1
Grand
Lake
Lake
Melville
North West River
km

Figure 2: *Geology of the North West River area (13F/9), Labrador.*

the major northeast trending thrust, sillimanite is the representative aluminosilicate and occurs as fine fibrolite aggregates within the same mineral assemblage as kyanite. An approximate isograd has been drawn to separate the kyanite and sillimanite fields (Figure 2). The two minerals have not been observed together and their mutual time relationships are uncertain.

An exposure of the metasedimentary gneisses on the north shore of Grand Lake (Figure 2) contains 1 to 3 m wide interbands of a green banded gneiss with the composition biotite + hornblende + epidote + diopside (?), and contains irregular segregations of coarse intergrown garnet, quartz and plagioclase. These rocks are apparently of calc-silicate composition and resemble rocks found in association with other metasedimentary gneisses in more easterly parts of the Grenville Province (Gower, personal communication, 1983).

Legend for Figure 2

⁘	*Pleistocene drift*
HELIKIAN	
	Cape Caribou River Allochthon
7	*Massive, coarse grained anorthosite.*
6b	*Interlayered gabbro, leucogabbro and minor anorthosite, passing structurally downwards into metagabbroic equivalents.*
6a	*Amphibolite and leucoamphibolite.*
5	*Interlayered, mylonitized amphibolite, mafic granulite and white granite.*
	Thrust Contact
	Granitoids
4	*Coarse grained, megacrystic biotite granite.*
3	*Fine grained tonalite and microgranite.*
	Pre-Grenville Gneisses
2	*Granitoid gneisses: generally gray, migmatitic granodiorite gneisses with abundant amphibolite bands.*
2a	*Gray quartz diorite to tonalite gneiss.*
APHEBIAN (?)	
1	*Kyanite-sillimanite-bearing, gray to pink, migmatitic metasedimentary gneisses.*

Late crosscutting quartz + feldspar pegmatites are abundant within the metasedimentary gneisses, and locally contain between 10 and 35% of a metallic mineral preliminarily identified as ilmenite. On the north shore of Grand Lake the gneisses are intruded by a single late mafic dike which crosscuts gneissic banding but was folded and recrystallized during a later deformation.

The gneisses of Unit 1 are generally similar in composition and structural style to extensive belts of metasedimentary gneiss in the Grenville Province of central Labrador (see Ryan et al., 1982; Thomas, 1981; Thomas et al., 1981). These gneisses, generally termed Disappointment Lake gneiss (Thomas, 1981), have been dated at circa 1650 Ma by Rb-Sr method (Fryer *in* Thomas, 1981), an age interpreted to represent the timing of high grade metamorphism in the unit. The protolith of these gneisses, as with those of the present map area, is believed to have been a predominantly pelitic-psammitic sequence, probably of early Proterozoic age.

Unit 2: Granitoid Gneisses

This is a heterogeneous unit underlying much of the northeastern half of the map area (Figure 2).

The predominant lithology is a gray gneiss of overall granodiorite composition which is usually strongly migmatitic with a tonalite paleosome and a granodiorite to granite leucosome. The overall mineral composition is quartz + feldspar + biotite + magnetite ± hornblende ± garnet ± epidote. Garnet occurs only in minor amounts and hornblende is largely found in the leucosome fraction. Epidote is a common constituent in the northwestern part of the unit. Scapolite has been found locally in mylonitized equivalents of the gray gneisses. Typical accessory minerals are monazite, apatite, allanite, zircon and sphene; monazite being unusually abundant at some localities.

South of Grand Lake, isolated localities of granodiorite gneiss have been found containing orthopyroxene in association with the above mentioned assemblage.

The gray granodioritic gneisses are interbanded on a variety of scales with pink granite gneisses which have the monotonous assemblage quartz + feldspar + biotite ± garnet.

A subunit of gray, quartz diorite to tonalite gneiss (2a) has also been recognized along the northern shore of Grand Lake. This subunit is generally less migmatitic and gneissic than the neighboring granodiorite gneisses, and contains recognizable relict igneous features such as attenuated amphibolite xenoliths, augened plagioclase megacrysts and amphibolite dikes which locally retain angular apophyses and recrystallized chilled margins. The inland extension of this unit is poorly defined. These gneisses have the assemblage quartz + feldspar + hornblende + biotite + magnetite ± garnet ± clinopyroxene ± orthopyroxene. They are typically hornblende-rich and locally contain abundant garnet porphyroblasts. Clinopyroxene is well preserved but orthopyroxene is highly altered and partially replaced by biotite.

All gneisses of Unit 2 contain abundant bands and boudins of amphibolite, locally forming up to forty percent of outcrops. In low strain zones these have rectilinear shape and are recognizable as relict dikes (Plate 2). Larger, outcrop scale bodies of amphibolite, locally preserving a vague compositional banding, are also present within all Unit 2 gneisses and may be genetically related to the dikes. The amphibolites have the general assemblage plagioclase + hornblende + biotite + Fe Ti oxides ± clinopyroxene ± minor orthopyroxene. Pyroxene, largely clinopyroxene, but including orthopyroxene has been observed only in rocks south of Grand Lake. The mafic rocks of Unit 2 in this area are, therefore, more correctly referred to as mafic granulite.

Plate 2: *Relic amphibolite dikes in granitoid gneisses of Unit 2.*

The granodiorite gneisses exposed along the north shore of Grand Lake have been intruded by scattered late mafic dikes generally similar to the example noted from the metasedimentary gneisses. These are characteristically dark green in color, and consist of a recrystallized intergrowth of amphibole, plagioclase and garnet. They crosscut the gneissic and migmatite fabrics of the host rocks at acute angles (Plate 3) but were later cleaved, folded and recrystallized.

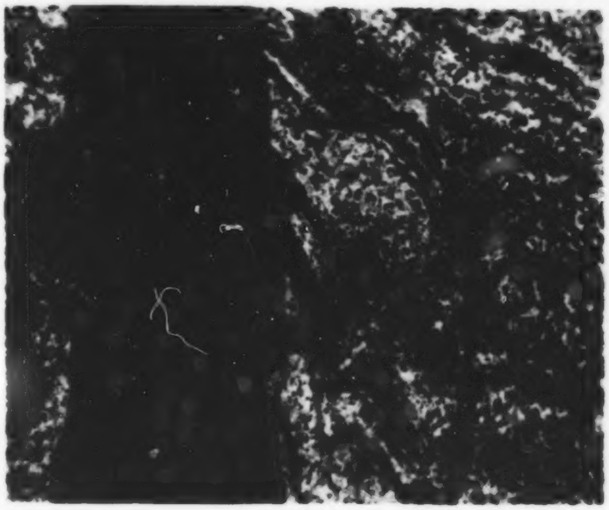

Plate 3: *Late amphibolite dike crosscutting gneissic banding in Unit 2 granitoid gneiss.*

The contact between Units 1 and 2 is exposed on the north shore of Grand Lake, where granodiorite gneisses of Unit 2 are interlayered with the metasedimentary gneisses on a scale of 1 to 2 m. However, the evidence is ambiguous as to whether this is a tectonic effect or reflects an original intrusive relationship.

The granitoid gneisses of Unit 2 extend to the north where they have been described by Erdmer (1983, *his unit 2)* and dated at 1680 Ma (U-Pb zircon, Krogh, written communication, 1983) an age which is presumed to approximate the timing of high grade metamorphism and migmatization in the unit. This is consistent with other circa 1650 Ma metamorphic ages obtained from the Disappointment Lake gneiss of central Labrador and indicates a major early Proterozoic metamorphic event within the central and eastern Grenville Province. This is referred to by Nunn et al. (1984) as the Labradorian orogeny.

Unit 3: Fine Grained Tonalite-microgranite

Four small, separate outcrops consisting of fine grained, weakly foliated granitoid rocks occur north of Grand Lake in the central part of the area (Figure 2). One outcrop comprises a fine grained gray tonalite or granodiorite; the others are pink leucocratic microgranites. The outcrops may belong to one large composite pluton, but more probably represent small isolated intrusions. The weakly foliated state suggests that intrusion followed the main metamorphic episode in the host gneisses.

Unit 4: Megacrystic Granite

Two small bodies of biotite megacrystic granite intruded Unit 2 gneisses near the southeastern end of Grand Lake (Figure 2). The westernmost body is in reality a network of granite dikes rather than a homogeneous pluton. The granites contain K-feldspar megacrysts 2 to 3 cm diameter set in a matrix of quartz, plagioclase and coarse biotite. They are weakly foliated and clearly crosscut gneissic fabrics in the Unit 2 host rocks.

Unit 5: Interlayered, Strongly Mylonitized Amphibolite - Mafic Granulite, Leucoamphibolite and white Granite

This forms the strongly tectonized basal unit of the Cape Caribou River allochthon (Figure 2). The unit typically is a well layered sequence (layers 2 to 30 cm thick) of dark, garnetiferous amphibolite - mafic granulite, varying to garnetiferous leucoamphibolite with concordant layers of white granite. The white appearance is deceptively suggestive of tonalite, and it is only after staining that the relatively K-feldspar-rich nature of these sheets is apparent. The granite sheets typically range between 0.5 cm and 30 cm in thickness and more rarely up to a metre. They are all parallel and interspersed with amphibolite layers of similar thickness (Plate 4). The highly concordant nature of the layering is undoubtedly in large part a tectonic effect and reflects the extremely high strain developed at the base of the Cape Caribou River allochthon. Locally granite veins have been observed to be isoclinally folded and also to crosscut amphibolite layers at shallow angles.

The mafic layers contain the assemblage green hornblende + plagioclase + magnetite + clinopyroxene ± orthopyroxene ± garnet. Garnet is usually abundant in these rocks, forming poikilitic porphyroblasts from 0.5 to 3 cm in diameter, but is not always present. Green clinopyroxene, probably diopside, is the dominant pyroxene and is locally overgrown by green hornblende. Orthopyroxene is relatively rare in the mafic layers. The mafic rocks are commonly medium grained, with strong schistose fabrics wrapped around garnet porphyroblasts. The latter locally preserve helicitic inclusion trails indicative of rotation during growth.

Plate 4: *Interlayered, strongly mylonitized amphibolite - mafic granulite, and white granite of Unit 5. (G = granite).*

The granitoid layers vary locally to tonalite, and contain the assemblage quartz + feldspar + magnetite ± clinopyroxene ± orthopyroxene ± garnet ± biotite. They show well developed mylonite texture with thin ribbon quartz grains enclosing elongate augen of feldspar, pyroxene and garnet. On the microscopic scale this cataclastic texture has been recrystallized to a polygonal granular texture.

The origin of Unit 5 and its relationships to the overlying metagabbroic and anorthosite rocks of the Cape Caribou River allochthon are uncertain. The amphibolite - mafic granulite component of Unit 5 is practically identical in appearance to the amphibolite component of the structurally overlying layered amphibolites (Unit 6a) of the gabbro-anorthosite suite. However, nowhere is it possible to trace a continuous section from one unit to the other and there is only permissive evidence for a gradational contact. On the other hand the interlayering of amphibolite and granite is also broadly similar to highly straightened and mylonitized amphibolite-rich parts of the Unit 2 granitoid gneiss complex. Thus the question arises as to whether Unit 5 forms the tectonized base of the gabbro-anorthosite suite, or is an allochthonous slice of basement.

Crucial to the resolution of this question is the origin of the granitic sheets within Unit 5. Significantly these sheets do not show any indication of having had gneissic texture prior to mylonitization and appear to be derived from mylonitization of granites rather than thin slices of basement gneiss. They also locally show crosscutting relationships with amphibolite bands indicating an original intrusive relationship. This is further supported by the local presence of irregular sheets of white granite in the overlying amphibolites (Unit 6a) of the gabbro-anorthosite suite (see below).

We suggest, therefore, that the granite sheets were intruded into an amphibolite - mafic granulite sequence presumed to form the base of the gabbro-anorthosite suite. The origin of the granites is unknown. It is possible that they represent a transposed stockwork system produced at the contact zone of a deep level granite pluton. Alternatively they could be interpreted as the products of rheomorphic injection following melting of granitoid host rock by intrusion of the gabbro-anorthosite suite; or possibly the products of frictional melting related to thrusting. In each case it is likely that they mark the basal contact zone of the gabbro-anorthosite suite.

As a final point it is worth noting that for the western part of the Cape Caribou River allochthon, (Figure 1) Ryan et al. (1982) demonstrated the lowest part of the allochthon to consist of gray granite to granodioritic gneisses. Most of these rocks are extensively mylonitized but usually they retain vestiges of gneissic fabric and as such are distinct from the rocks of Unit 5.

Unit 6: Gabbro-amphibolite

Unit 6 represents a variably deformed and recrystallized gabbroid body, the lower part of which consists of amphibolite (Unit 6a) and the upper part gabbro-metagabbro (Unit 6b).

Unit 6a: Amphibolite-leucoamphibolite

Unit 6a consists of banded amphibolite and leucoamphibolite interpreted to form the metamorphosed and recrystallized base of the layered gabbros and metagabbros of Unit 6 (Figure 2). The rocks generally appear as dark to buff amphibolites in which layering is often strikingly well preserved (Plate 5), and show variation in composition from ultramafic to leucoamphibolite and meta-anorthosite. Layering is invariably concordant with foliation and dips at shallow angles to the south and southwest. Well developed and clearly exposed layering is present on the shores of Grand Lake. To the south, and presumably upward in the structural pile, the amphibolites are more massive and pass gradationally into the metagabbros of Unit 6b.

Plate 5: *Layered amphibolite - leucoamphibolite of Unit 6a.*

Unit 6a comprises the general assemblage plagioclase + clinopyroxene + magnetite + hornblende ± garnet ± biotite ± quartz. Orthopyroxene has not been observed in any part of the unit, in contrast to the amphibolite - mafic granulite rocks of Unit 5. Clinopyroxene, probably diopsidic, is clearly of metamorphic origin and is unstable with respect to hornblende.

Contact relationships with underlying Unit 5 are, as discussed above, unexposed. Ryan et al. (1982) described thick dikes of metagabbro-amphibolite which intrude the allochthonous granitoid gneisses at the base of the western part of the allochthon. The metagabbros are apparently related to the gabbro-anorthosite suite and crosscut gneissic banding within the gneisses, indicating that intrusion of this suite followed the principal period of deformation and metamorphism in the basement (Unit 2) gneisses.

Unit 6b: Interlayered gabbro, leucogabbro and minor anorthosite

This unit structurally overlies Unit 6a. The metagabbros are distinguished from the amphibolites of 6a on the basis of preservation of relict igneous texture and lack of the strong foliation characteristic of the amphibolites.

The metagabbros show a considerable compositional range from coarse grained leucogabbros and very rare anorthosite, to medium grained gabbros and more rarely to thin ultramafic bands. The most prevalent rock type is dark, massive to weakly foliated, medium grained gabbro. Layering, generally dipping shallowly to the southwest, is usually developed on a scale of metres and is less striking than in the amphibolites of Unit 6a. The metagabbros generally retain partial igneous mineral assemblages, *viz.* plagioclase + orthopyroxene + clinopyroxene. These have been largely recrystallized on the microscopic scale, with development of green hornblende rims around pyroxene, and growth of minor garnet in grain interstices.

The metagabbros at one locality on the Cape Caribou River are intruded by an irregular system of white granite sheets which predate the single Grenvillian(?) fabric present in these rocks. They may be genetically related to the granite sheets of Unit 5.

Unit 7: Massive, coarse grained anorthosite

The anorthosite forms the core and the highest structural level of the Cape Caribou River allochthon (Figures 1 and 2). The unit is largely composed of coarse grained, white to gray anorthosite-leucogabbro with a mafic content of less than 35 percent. Large labradorite crystals (1 to 4 cm long) are typical and locally range up to 50 cm in length. Orthopyroxene forms interstitial plates, usually intergrown with magnetite and/or ilmenite, but also occurs as discrete giant crystals which range up to 50 cm in diameter. These giant crystals usually interfinger at their margins with tabular plagioclase crystals of the host anorthosite, and appear to be intercumulus.

The anorthosite is largely homogeneous and layering is usually seen only as a local ribbing produced by differential weathering. Rhythmic compositional layering is locally found around the margins of the anorthosite (Plate 6) where it grades into gabbro of Unit 6b. Where sufficiently well exposed, layering indicates the unit to be right way up.

A pervasive plagioclase-pyroxene mineral lamination is found in many parts of the anorthosite and is of primary origin. The lamination is parallel to layering and dips moderately to the west and southwest.

Plate 6: *Rhythmic leucogabbro-anorthosite layering in Unit 7 anorthosite.*

In thin section the anorthosite is seen to largely retain igneous texture in the form of cumulate plagioclase with interstitial intergrowths of orthopyroxene, clinopyroxene and Fe Ti oxides. Pyroxene is partly rimmed by green hornblende and in some samples has also developed partial garnet coronas.

The pyroxenes are also internally recrystallized, and clinopyroxenes typically contain internal trains of hypersthene grains which probably developed by recrystallization of exsolution lamellae in a primary augitic pyroxene.

The anorthosite is intruded by several rectilinear mafic dikes which may be far more numerous than indicated by available outcrop. These have predominant northwest strikes, although it is evident in some outcrops that at least two dike sets are present. The dikes locally retain chilled margins but have been internally recrystallized to microcrystalline aggregates of plagioclase, garnet, green hornblende, magnetite and clinopyroxene. An oblique or wall-parallel fabric is locally developed within the dikes, but otherwise mineral fabrics are isotropic.

A variety of pretectonic granitoid dikes and sheets ranging from white tonalite to pink granite, monzonite and pegmatite intrude the anorthosite and the mafic dikes. These may be related to a suite of granites which intrude the western part of the Cape Caribou River allochthon (Ryan et al., 1982) (Figure 1).

The contact of the anorthosite with the structurally underlying metagabbros is gradational and interlayered over a distance of about 1 km.

The age of the anorthosite and its associated gabbros is constrained only by the 1650 Ma of deformation in the Unit 2 gneisses and the 1000 Ma age of the Grenvillian Orogeny. The typical anorthosite event in Labrador, termed the Elsonian event (Emslie, 1978), occurred around 1450 Ma. However, Emslie (1978) established a minimum age for the nearby Mealy Mountains anorthosite of 1640 Ma (based on Rb-Sr and U-Pb zircon ages for monzonites intruding the anorthosite).

Structural Development

The dominant structural feature of the area is the Cape Caribou River thrust which conveniently divides the area into two major structural domains: a northeastern gneiss domain, which may again be internally subdivided by the northeast trending thrust; and a southeastern domain represented by the Cape Caribou River allochthon.

Northeastern Gneiss Domain

This comprises the metasedimentary gneisses of Unit 1, the extensive granitoid gneisses of Unit 2 and the minor granitoid intrusives of Units 3 and 4. Structural trends within the domain are variable with dips varying from steep to shallow to the south, southeast and southwest. Superimposed upon the gneissic and migmatitic fabrics are a number of ductile shear zones of northeast trend. The most important of these follows a major negative aeromagnetic lineament (Figure 2) and is interpreted to form the southwestern extension of a major thrust - ductile shear zone which has been mapped in the area to the northeast by Erdmer (1983). The thrust is only locally exposed within the map area, and is characterized by flaggy schistose and mylonitic gneisses with shallow southeasterly dips and southeast plunging mineral lineations. Based on comparisons with other areas of thrusting in the northern Grenville Province (e.g. Thomas, 1981) the age of the thrust is assumed to be Grenvillian, although this is by no means certain. It was apparently overridden by the Cape Caribou River allochthon (Figure 2).

In the southwestern part of the domain, the gneissic fabrics were reoriented into the northwesterly structural trends associated with the basal thrust zone of the Cape Caribou River allochthon. Adjacent to this thrust, the gneisses were strongly straightened and overprinted by mylonitic ductile shear zone fabrics (Plate 7). In general, however, the degree of mylonitization is far less than that present in the upper thrust plate. Both reoriented gneissic fabrics and superimposed shear fabrics dip at shallow to moderate angles to the southwest. Fabrics in the southeastern part of thrust generally have steeper attitudes (40 to 60°) than those in the northwest near the nose of the lobate thrust (10 to 20°).

Plate 7: *Augen mylonite derived from granitoid gneisses, Unit 1. Associated with Cape Caribou River thrust zone.*

The foliation geometry of the northeast domain is summarized in the stereonet plot (Figure 3a). The diagram shows two maxima which indicate northeast structural trends, with moderate to shallow southeasterly and northwesterly dips. The opposing dips are probably related to folding about gently northeast plunging folds with northeast trending axial traces. The spread of points in the northeast quadrant of the diagram is attributed to refolding of these foliations into southwesterly dipping attitudes. This occurred primarily in association with development of the Cape Caribou River allochthon.

Also associated with structural reorientation are zones of second phase (F_2) folding. In general these folds are tight to isoclinal in style, are reclined to the northeast, and plunge moderately to the southeast or west. Their axial planes are generally coplanar with reoriented gneissic fabrics and are locally associated with second phase (S_2) biotite fabrics. These minor structures are not shown on the Figure 2.

A pervasive feature of the overthrust zone is the development of a strong mineral lineation (Figure 2), plunging southeast between 0° and 40°. The lineation and fold vergence, taken together, indicate tectonic transport on the Cape Caribou River thrust to have been to the northwest at 320°. Lineations for the northeast domain are summarized in Figure 3c. The predominant southeasterly plunging lineations were partly refolded by F_3 folding into shallow northwest plunging lineations.

A late period of open folding about north-south subhorizontal axes affected the rocks in the vicinity of the Cape Caribou River thrust. These folds (not shown in Figure 2), which are generally only discernible in the Grand Lake shoreline exposure, have variable shallow plunge directions to both north and south, and produced periclinal undulations of earlier fabrics. This period of folding is probably responsible for the local north dipping attitude of foliations and north plunging lineations seen north of Grand Lake.

Cape Caribou River Allochthon Domain

Much of the deformation associated with the development and translation of the allochthon was taken up within the amphibolites and granites of Unit 5. These rocks are highly straightened, thoroughly mylonitic with pronounced ribbon quartz fabrics, and possess strong southeast plunging mineral lineations. Isolated, rootless isoclinal fold closures have been noted indicating that the regular layered appearance of Unit 5 probably represents an extremely high strain state.

The amphibolites of Unit 6a are strongly foliated and deformed into numerous tight to isoclinal folds reclined to the north. These are readily seen from the air on the cliffs of Cape Caribou.

Penetrative deformation dies out upward into the gabbro-anorthosite suite rocks and, in the upper levels of the allochthon, is restricted to thin isolated brittle shear zones of irregular trend, and pervasive fracturing and granulation.

Foliation attitudes within the allochthon are summarized in Figure 3b. The diagram shows a partial girdle of northwest-southeast strike which is consistent with the shallow to moderate easterly, southerly and southwesterly dips seen in the allochthon. The easterly dips are due to readings taken from the nose region of the allochthon west of the map area. Two subsidiary girdles have been superimposed upon the principal girdle; a well defined northeast-southwest one, and a less well defined north-south one. Both are interpreted as the result of late periclinal refolding, largely about northwest-southeast trending axes. This fold episode is correlated with the similar F_3 folds seen in the northeastern domain.

Lineation directions within the allochthon are summarized in Figure 3d. Again these have been affected by F_3 refolding. Overall lineation directions are very similar to those of the northeastern structural domain, as shown by the combined lineation plot (3e) for the two domains.

The development of the Cape Caribou River allochthon and its associated structures is, at present, assumed to be a Grenvillian event, by analogy with most of the other north directed thrusting along the northern margin of the Grenville Province.

Post-Grenvillian Structures

A series of northeast trending lineaments is apparent on aerial photographs of the North West River area (see also Figure 2). Some of these may be associated with development of the northeast trending thrust and ductile shear zone structures; however, the majority appear to crosscut these earlier structures. Significantly the bluffs which mark the abutment of bedrock against the Pleistocene drift of the Lake Melville lowlands also follow a partial northeast topographic trend (Figure 2) and may be locally fault-controlled. The general trend of both lineaments and interpreted faults is parallel to that of the late Precambrian - early Paleozoic Lake Melville graben system (Kindle, 1924; Erdmer, 1983) which is locally floored by the Upper Precambrian - lower Paleozoic Double Mer Formation sandstones. By inference it is proposed that the prominent lineaments of the map area are fracture-controlled and related to this period of crustal extension. It is also conceivable that the faults (which are interpreted to control the eastern exposures of Precambrian crystalline bedrock against the Lake Melville lowlands) are graben boundary faults which dropped Upper Precambrian - lower Paleozoic sedimentary rocks down against the crystalline rocks. In this model, the Pleistocene-covered Lake Melville lowlands around North West River and Lake Melville could be underlain at depth by rocks broadly equivalent to the Double Mer Formation.

Metamorphic Development

Northeastern Gneiss Domain

Metamorphic assemblages in the metasedimentary gneisses of Unit 1 show a transition from the assemblage kyanite + K-feldspar + quartz + plagioclase + biotite + magnetite ± garnet in the north to one similar, but with sillimanite rather than kyanite, near the northeast trending thrust which transects the domain. Kyanite + K-feldspar are present in stable association with melt phases indicated by the

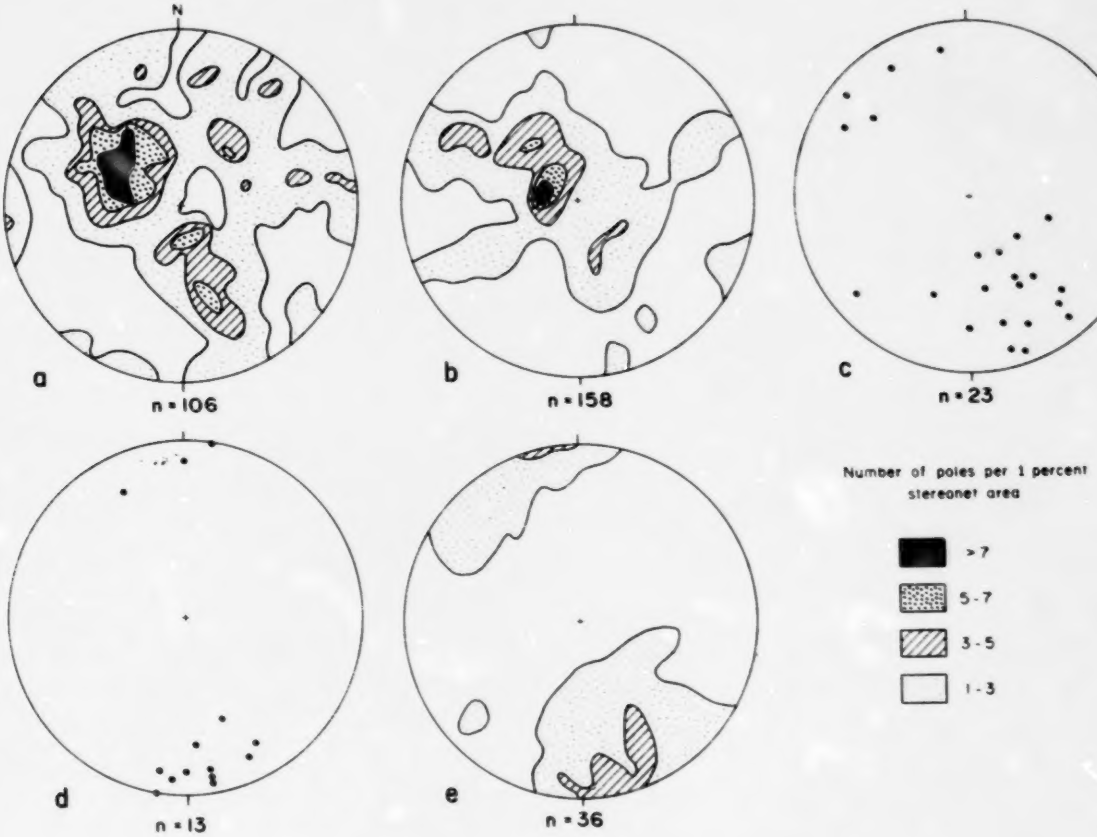

Figure 3: *Stereonet plots, poles to foliation: lineations*
3a - *northeastern (autochthonous) structural domain;*
3b - *Cape Caribou River allochthon;*
3c - *lineations, northeastern (autochthonous) structural domain;*
3d - *lineations, Cape Caribou River allochthon;*
3e - *combined lineations, Cape Caribou River allochthon and northeastern structural domain.*

migmatite textures and represent an extremely high pressure - high temperature assemblage of approximately 7 kb, 650°C (Carmichael, 1978). Erdmer *(in preparation)* has determined PT conditions of 8.5 - 9.0 kb at 700°C for rocks similar to these northeast of the map area. The southerly transition to a sillimanite-bearing assemblage may reflect either an isobaric increase in temperature, or a transition to lower pressures. Erdmer *(in preparation)* has calculated higher metamorphic temperatures (660° - 890°C) for rocks south of the thrust in the region to the northeast of the map area.' There are no independent pressure estimates available.

Metamorphic assemblages in the granitoid gneisses generally indicate amphibolite facies conditions. However relict orthopyroxene in rocks south of Grand Lake and in Unit 2a indicates that at least the southern part of the granitoid gneisses were subject to granulite grade metamorphism. In the northeastern part of the granitoid gneisses, epidote is a stable component of the paragenesis in association with hornblende, garnet and biotite.

Peak metamorphic conditions in both metasedimentary and granitoid gneisses are believed to have been attained in the circa 1650 Ma event. This is indicated by both the U-Pb zircon date of Krogh (written communication, 1983) which shows very little evidence of a post-1650 Ma disturbance, and by the late mafic dikes (described under Unit 2) which crosscut a gneissic banding that must be pre-Grenvillian in age. Ductile shearing associated with development of the Cape Caribou River allochthon was associated with the development of second biotite fabrics in granitoid gneisses, and hornblende-garnet fabrics in mafic rocks. Ductile shearing also produced widespread late muscovite growth in the metasedimentary gneisses.

Cape Caribou River Allochthon

Metamorphism associated with development of this structure was concentrated in the basal part of the allochthon, in Unit 5. The presence of orthopyroxene + clinopyroxene + hornblende + garnet assemblages in this unit, in both mafic and granitic components, is diagnostic of granulite facies conditions. It is possible that the granulite mineralogy was developed prior to thrusting, possibly as a contact aureole effect under the gabbro-anorthosite suite. However it is also apparent that these granulite assemblages remained stable during what must have been a largely anhydrous thrust - ductile shear regime. Ryan et al. (1982) also described granulite facies assemblages from mylonitic granitoid gneisses at the base of the western part of the allochthon.

Metamorphic assemblages in the amphibolites of Unit 6a and the metagabbros of Unit 6 are characterized by plagioclase + clinopyroxene (diopside) + hornblende assemblages. Clinopyroxene, probably derived by recrystallization of igneous pyroxene, was only locally hydrated to hornblende, also suggesting a largely anhydrous deformation and recrystallization. Primary orthopyroxene is only found in the less deformed gabbros; elsewhere it recrystallized to clinopyroxene + hornblende.

The anorthosite of Unit 7 has largely retained its igneous mineralogy. Pyroxene developed thin partial garnet coronas in what may have been either a cooling or a metamorphic reaction with plagioclase. However, the dominant metamorphic effect was the development of thin hornblende and biotite rims around pyroxene grains.

The lack of well developed clinopyroxene, garnet or spinel corona textures in the gabbro-anorthosite suite is very noticeable and contrasts with other gabbroid suites present in the northern part of the Grenville Province (see Emslie, 1983; Wardle, in preparation; Rivers, 1983). This probably indicates that the gabbro-anorthosite rocks of the Cape Caribou River allochthon never experienced the very deep burial conditions (greater than 6-9.5 kb), generally considered necessary to produce these assemblages (e.g. Griffin and Heier, 1969).

It is presumed that development of peak metamorphic assemblages within the Cape Caribou River allochthon was a Grenvillian event, although as noted above some of the granulite mineralogy within the base of the allochthon may be pre-Grenville.

Brittle movement along both the Cape Caribou River thrust and the northeast trending thrust followed the main period of ductile shearing and was associated with low grade chlorite-epidote-muscovite retrogressive alteration.

Mineralization

The anorthosite (Unit 7) contains abundant magnetite and some ilmenite, usually intergrown with pyroxene; however, large concentrations have not been seen. The interior parts of the anorthosite locally contain iridescent labradorite (Figure 2) and may have potential for building or facing stone. However the pervasive fracturing and granulation probably detract from this potential.

Small showings of fluorite have also been found associated with sheared granite veins within the anorthosite (Figure 2). Fluorite occurs largely as a thin veneer on joint and fracture surfaces.

Pegmatites within the metasedimentary gneisses of Unit 2 locally contain concentrations (10 to 30 percent) of a gray metallic mineral tentatively identified as ilmenite. In the best locality, a small tongue of gneiss south of the main metasedimentary gneiss belt (Figure 2), the mineralization extends over an area of at least 40 m^2.

Summary and Discussion

The early history of the map area is recorded in the northeastern part of the area where a gneiss terrane composed of metasedimentary and granitoid gneisses experienced a major pre-Grenvillian event of high grade metamorphism and deformation. The available isotopic data suggest that this occurred circa 1650 Ma. The possibility must also be considered that the terrane has an even older crustal history, although this has yet to be confirmed by isotopic dating.

The northeastern domain is dissected by a thrust which continues for over 50 km to the northeast to where it is hidden under Lake Melville. Gower (1983, 1984) and Erdmer (1983) have noted that this thrust separates a southern terrane (Lake Melville terrane), characterized by an abundance of megacrystic granites, sillimanite-bearing metasedimentary gneisses, and local granulite facies domains, from a northern terrane (Groswater Bay terrane) characterized by a prevalence of epidote-bearing granitoid gneisses, and kyanite-bearing metasedimentary gneisses.

To a limited extent these differences are also recognized within the North West River area. Small amounts of megacrystic granitoid and granulite facies rocks are found south of the northeast trending thrust, termed the Rigolet thrust zone by Gower and Owen *(in preparation)*, whereas kyanite-bearing metasedimentary gneisses and epidote-bearing granitoid assemblages are found north of it. There is also a transition from kyanite- to sillimanite-bearing assemblages towards the thrust suggesting that, if metasedimentary gneiss were exposed, sillimanite-bearing assemblages might also be found south of the thrust. In other respects, however, the granitoid gneiss shows very little compositional or structural change across the thrust and it appears that the main effect of thrusting has been to juxtapose high temperature (Erdmer, *in preparation*) assemblages in the south against lower temperature - high pressure assemblages in the north.

The thrust is presumed to have developed during the Grenville Orogeny and was associated with north-northwesterly directed structural translation. It was then overridden by another Grenvillian thrust structure, the lobate Cape Caribou River allochthon, which was translated in a similar direction.

The upper part of the allochthon comprises anorthosite which passes down through gabbros into layered metagabbros and amphibolites. The basal part of the allochthon is an enigmatic unit consisting of mylonitized amphibolite and mafic granulite, proposed to be a basal part of the gabbro-anorthosite suite sheeted by granite. The unit is thought to represent the basal contact zone of the gabbro-anorthosite suite but the possibility cannot be ignored that it forms part of the basement.

Granulite facies assemblages in the basal part of the allochthon remained stable during overthrusting and mylonitization, indicating largely anhydrous conditions of metamorphism.

Following the Grenvillian Orogeny the area was stabilized and, in the late Precambrian, subject to an episode of extensional tectonism associated with development of the Lake Melville graben. It is speculated that the Pleistocene-covered expanse of the Lake Melville lowlands may represent a part of the graben floor and be underlain at depth by Upper Precambrian - lower Paleozoic sedimentary rocks.

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R.J. Wardle

GEOLOGY OF THE DOUBLE MER WHITE HILLS AND SURROUNDING REGION, GRENVILLE PROVINCE, EASTERN LABRADOR[1]

by

Charles F. Gower

Gower, C.F., Geology of the Double Mer White Hills and surrounding region, Grenville Province, eastern Labrador: in Current Research, Part A, Geological Survey of Canada, Paper 84-1A.

Abstract

The Double Mer White Hills and surrounding region is located near the northern margin of the Grenville Province in eastern Labrador and includes parts of three major crustal segments, namely the Trans-Labrador batholith, the Groswater Bay terrane and the Lake Melville terrane.

The Trans-Labrador batholith comprises two granitoid units, the Walker Lake quartz monzonite and the Crooked River granite, which are inferred to have been emplaced ca. 1650-1600 Ma. The Groswater Bay terrane comprises muscovite- and kyanite-bearing paragneiss, dioritic, granodioritic and granitic orthogneiss, and foliated to gneissic plutons of muscovite-biotite granite and pyroxene quartz syenite. The Lake Melville terrane is located south of the Groswater Bay terrane and separated from it by thrusts or post-Grenvillian faults. It includes kyanite or sillimanite + K-feldspar paragneiss, granitic orthogneiss and granulite facies gabbroic, monzonitic and granitic rocks. Age relationships of these units are unquantified but evidence from adjacent areas suggests that the paragneiss is Aphebian, and remained as remnants after extensive plutonism which probably ceased ca. 1600 Ma.

The area was subsequently intruded by mafic rocks, probably of several ages, especially the Michael gabbro (ca. 1400 Ma). The Double Mer Formation, which consists of unmetamorphosed arkose and conglomerate, was deposited in a post-Grenvillian half-graben.

Introduction

Systematic 1:100,000 scale geological mapping in Labrador during the past five years by the Newfoundland Department of Mines and Energy has focussed on the northern margin of the Grenville Province. Mapping of the area described in this report during the 1983 field season completes geological coverage along the entire length of the Grenville Front (Tectonic) Zone in Labrador.

The area, located in central-east Labrador (Figure 1), includes six NTS 1:50,000 sheet areas (13J/3, 13J/4, 13J/5, 13J/6, 13K/1, and 13K/8), which cover an area of approximately 5500 km^2. Preliminary results from the first year of the Canada-Newfoundland co-operative minerals program in eastern Labrador were reported by Erdmer (1983) who mapped NTS 1:50,000 sheet areas 13F/16, 13G/13 and 13G/14, immediately south of the present area.

Reconnaissance geological mapping at 1:250,000 scale was carried out by the Geological Survey of Canada: NTS sheet area 13K (east half) was mapped by Williams (1970) and 13J by Stevenson (1970). Present work has refined the distribution of rock units but, because of very low outcrop density, most geological boundaries and structural interpretation remain largely conjectural. In contrast, as samples were collected from nearly every outcrop, and have been slabbed, stained (K-feldspar specific) and compared in detail, lithological descriptions and grouping should be more valid.

Regional Setting

The area is located within the Grenville Province, partly straddling the Grenville Front Zone, as depicted by Gower et al. (1980). The line marking the northern "limit of widespread Grenville deformation" (Gower et al., 1980, page 787) is indicated on Figure 1.

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[1] Contribution to Canada-Newfoundland co-operative minerals program 1982-84. Project carried by Geological Survey of Canada and Newfoundland Department of Mines and Energy.

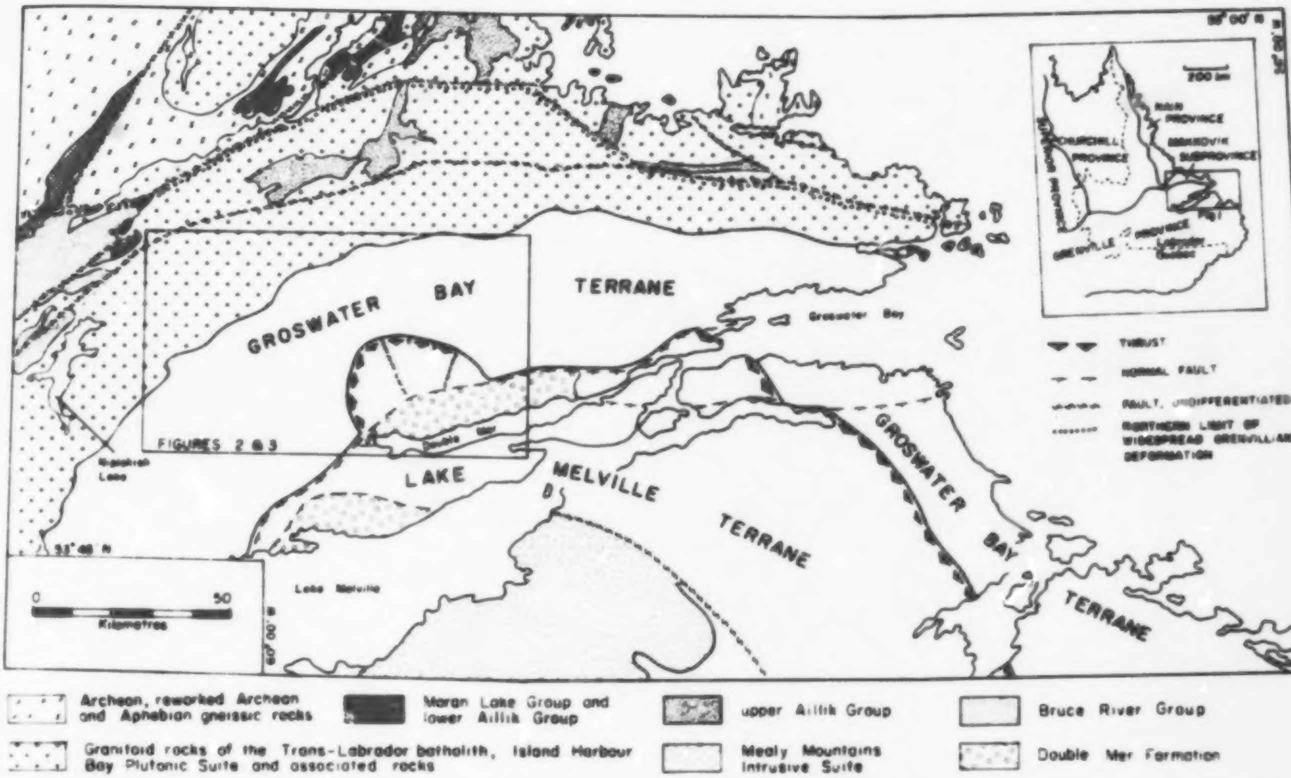

GROSWATER BAY TERRANE
FIGURES 2 & 3
LAKE MELVILLE TERRANE
GROSWATER BAY TERRANE
Groswater Bay
Double Mer
Lake Melville
0 50
Kilometres
53°45' N
60°00' W
56°00' W
55°00' N
200 km
RAE PROVINCE
MAKKOVIK SUBPROVINCE
CHURCHILL PROVINCE
SUPERIOR PROVINCE
GRENVILLE PROVINCE
Labrador Quebec
Fig 1
THRUST
NORMAL FAULT
FAULT, UNDIFFERENTIATED
NORTHERN LIMIT OF WIDESPREAD GRENVILLIAN DEFORMATION
Archean, reworked Archean and Aphebian gneissic rocks
Moran Lake Group and lower Aillik Group
upper Aillik Group
Bruce River Group
Granitoid rocks of the Trans-Labrador batholith, Island Harbour Bay Plutonic Suite and associated rocks
Mealy Mountains Intrusive Suite
Double Mer Formation

Figure 1: *Regional geological subdivisions of the Grenville Province in eastern Labrador*

The Trans-Labrador batholith (Wardle et al., 1982) is a belt of granitoid rocks along the northern flank of the Grenville Province across much of Labrador. Rock types include granodiorite, granite, quartz syenite and quartz monzonite, and individual plutons have generally yielded 1650-1600 Ma ages. The Trans-Labrador batholith intrudes felsic volcanic rocks of the upper Aillik Group (ca. 1750-1650 Ma) (Bailey, 1979; Gower, 1981). Elsewhere, the Trans-Labrador batholith is in part unconformably overlain by the Bruce River Group but includes plutons intrusive into the Bruce River Group (ca. 1530 Ma) (Ryan, 1981). The granitoid rocks are regarded as genetically related to felsic volcanic rocks in the upper Aillik Group and to similar rocks in the Bruce River Group (Bailey, 1979; Ryan, 1981). This implies plutonism/volcanism extending over a considerable length of time.

The terms Groswater Bay terrane and Lake Melville terrane refer to two constrasting geological regions recently identified by the author in the Grenville Province of eastern Labrador. These regions are structurally bounded crustal segments delineated on the basis of lithological associations, structural style and grade of metamorphism. Characteristics of these two terranes are detailed by Gower and Owen (in preparation) and are briefly summarized here.

Rock types in the Groswater Bay terrane include tonalite/granodiorite orthogneiss, pelitic/psammitic paragneiss, K-feldspar megacrystic granodiorite, diorite, pyroxene-bearing granitoid intrusive rocks and mafic rocks of various ages. Structural trends, where little modified by Grenvillian deformation, are north to northeast, and are similar to the Makkovik trend

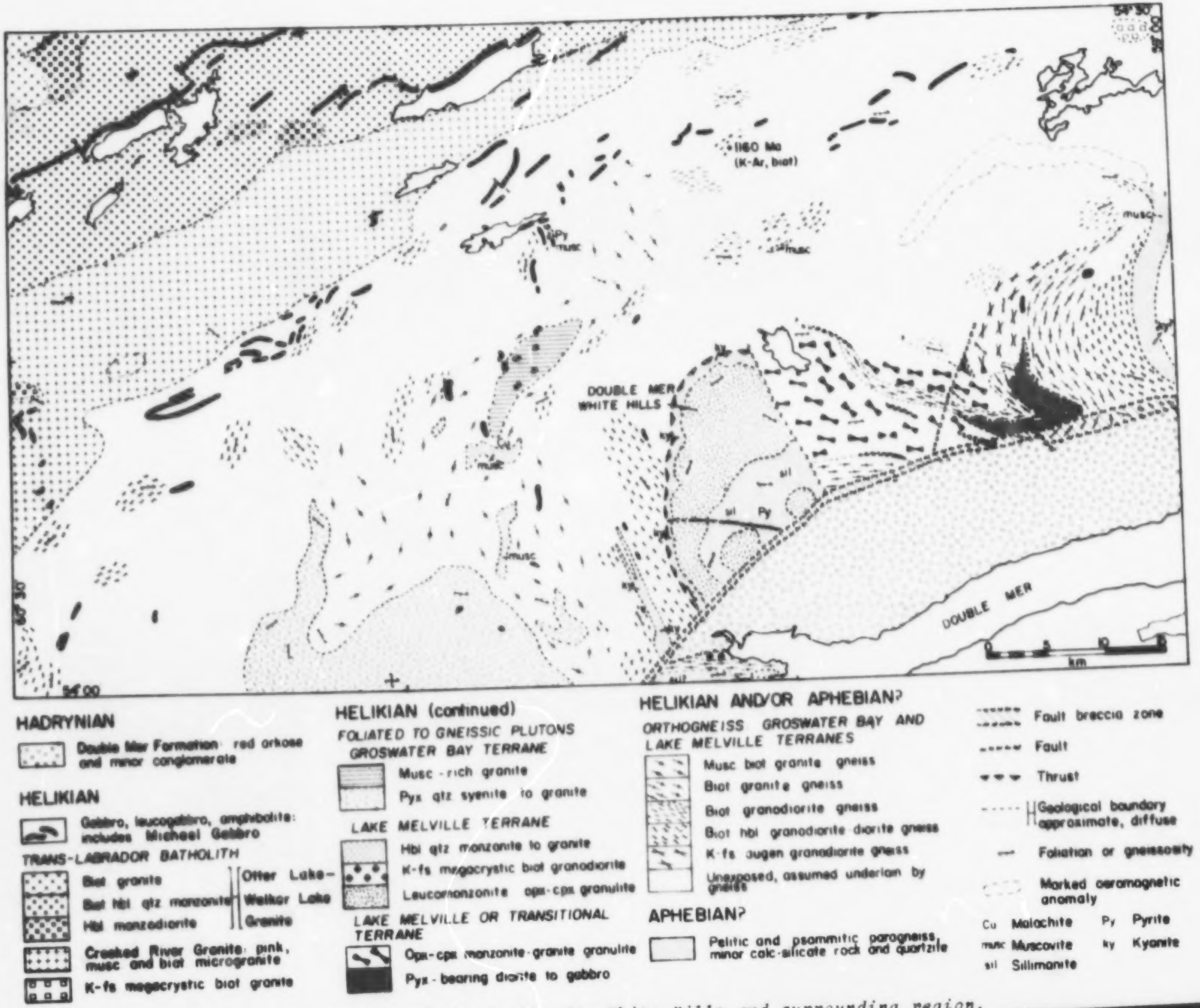

54°30'
60°30'
60°00'
54°00'
1160 Ma
(K-Ar, biot)
musc
Py
sil
DOUBLE MER WHITE HILLS
DOUBLE MER
km
0
5
10
15
HADRYNIAN
Double Mer Formation: red arkose and minor conglomerate
HELIKIAN
Gabbro, leucogabbro, amphibolite: includes Michael Gabbro
TRANS-LABRADOR BATHOLITH
Biot granite
Biot hbl qtz monzonite
Hbl monzodiorite
Otter Lake–Walker Lake Granite
Crooked River Granite: pink, musc and biot microgranite
K-fs megacrystic biot granite
HELIKIAN (continued)
FOLIATED TO GNEISSIC PLUTONS
GROSWATER BAY TERRANE
Musc-rich granite
Pyx qtz syenite to granite
LAKE MELVILLE TERRANE
Hbl qtz monzonite to granite
K-fs megacrystic biot granodiorite
Leucomonzonite opx-cpx granulite
LAKE MELVILLE OR TRANSITIONAL TERRANE
Opx-cpx monzonite-granite granulite
Pyx-bearing diorite to gabbro
HELIKIAN AND/OR APHEBIAN?
ORTHOGNEISS GROSWATER BAY AND LAKE MELVILLE TERRANES
Musc biot granite gneiss
Biot granite gneiss
Biot granodiorite gneiss
Biot hbl granodiorite-diorite gneiss
K-fs augen granodiorite gneiss
Unexposed, assumed underlain by gneiss
APHEBIAN?
Pelitic and psammitic paragneiss, minor calc-silicate rock and quartzite
Fault breccia zone
Fault
Thrust
Geological boundary approximate, diffuse
Foliation or gneissosity
Marked aeromagnetic anomaly
Cu Malachite
musc Muscovite
sil Sillimanite
Py Pyrite
ky Kyanite

Figure 2: *Geology of the Double Mer White Hills and surrounding region.*

in the Makkovik Subprovince. There is a metamorphic grade variation southward across the Groswater Bay terrane from greenschist to middle amphibolite facies.

Rock types in the Lake Melville terrane are similar to those in the Groswater Bay terrane, but proportions differ. For example, paragneiss is more extensive, and includes minor calc-silicate layers. Mafic rocks, except near the northern flank of the Lake Melville terrane, are less common. In contrast to relatively (deceptively?) simple structural patterns in the Groswater Bay terrane, the Lake Melville terrane shows chaotic structural trends. Also metamorphic grade is generally higher; the broad northern fringe of the Lake Melville terrane is characterized by medium pressure granulite facies rocks which grade southward into middle amphibolite facies assemblages.

The Mealy Mountains Intrusive Suite comprises leucotroctolite, leucogabbro, anorthosite and related rocks, intruded by pyroxene quartz monzonite (Emslie, 1976). It is bounded on its northwest and northeast sides by faults, but a southeast lobe appears to be intrusive.

Description of Rock Units

Trans-Labrador batholith

The Trans-Labrador batholith within the map area (Figure 2) comprises two contrasting granitoid units. In the north is the Walker Lake quartz monzonite, which is part of the broader Otter Lake - Walker Lake granite (Ryan, 1982).In the south is the Crooked River granite, also defined by Ryan (1982).

The Walker Lake quartz monzonite is dominantly a coarse grained, seriate textured, biotite hornblende quartz monzonite, but compositional variations include monzodiorite and granite. Mafic enclaves and minor intrusions are rare. No age dating has been carried out on the Walker Lake quartz monzonite within the map area, and geochronology has not been entirely successful elsewhere. Gower, Flanagan et al. (1982) summarized age data available to the end of 1981, which collectively indicate an age of ca. 1600 Ma. Subsequently Brooks (1983) has reported an age of 1628 ± 34 Ma (U-Pb, zircon) for biotite-hornblende quartz monzonite that previously yielded a 1595 ± 34 Ma (Rb-Sr) errorchron. However some doubt exists whether the quartz monzonite dated by Brooks is the same unit as that underlying the present map area (Ryan, personal communication, 1983).

The Crooked River granite is a homogeneous, fine to medium grained muscovite-biotite granite. Quartz veins, hematized fractures, and a lack of mafic enclaves are characteristic. Typically, the rock has a sugary texture, but where deformed takes on a schistose appearance, making it similar to feldspathic metasediment, a previously suggested protolith (Williams, 1970). Lack of bedding, homogeneity over wide areas, and intrusive contacts with other granitoid rocks confirm the plutonic nature of this unit.

A small area of K-feldspar megacrystic granodiorite occurs in the northeast corner of the map area. The rock is strongly foliated with K-feldspar augen up to 4 cm long. It has been included with the Trans-Labrador batholith but could equally well be grouped with the Groswater Bay terrane.

Groswater Bay Terrane

The Groswater Bay terrane is underlain by paragneiss, orthogneiss and foliated to gneissic plutons.

The paragneisses, by inference from evidence in adjacent areas, are assumed to be Aphebian in age, but may be Helikian. Volumetrically, they are a minor rock type in the Groswater Bay terrane. The most common lithologies are gray weathering, medium grained, quartzofeldspathic pelitic and semipelitic schists and gneisses. The gneissose varieties consist of alternating layers of a muscovite + biotite + opaque + garnet 'melanosome' (it is not melanocratic), and a coarser grained quartz + plagioclase ± K-feldspar leucosome. Locally the schists are ocherous weathering due to associated sulfides, largely pyrite but also minor arsenopyrite and/or chalcopyrite. Near the southern margin of the Groswater Bay terrane the pelitic rocks have kyanite- and K-feldspar-bearing assemblages. These are also muscovite-bearing but, pending petrographic examination, equilibrium relationships are uncertain. Kyanite was not positively identified in hand samples of pelites from the eastern part of the area, but it occurs in pelitic rocks immediately east of the map boundary (Gower, Gillespie et al., 1983). Other metasedimentary rock types within the Groswater Bay terrane include quartzite, calc-silicate rocks and layered amphibolite.

The orthogneisses include, in order of decreasing color index, (i) biotite-hornblende granodiorite-diorite gneiss, (ii) biotite granodiorite gneiss, (iii) K-feldspar augen granodiorite gneiss, (iv) biotite granite gneiss, and (v) muscovite-biotite granite gneiss. These gneissic types grade into each other and into more uniform, foliated granitoid units. The latter feature is a major reason for interpreting derivation from the igneous protolith.

Biotite-hornblende granodiorite-diorite gneiss is the most extensive and includes amphibolite enclaves, diorites and hornblende granodiorite gneiss. Particular compositional and textural varieties tend to be grouped in subareas, suggesting that they outline former plutons. The only age date available from the map area was obtained by Wanless et al (1972) for a rock here included as biotite-hornblende granodiorite-diorite gneiss. The age, 1160 ± 40 Ma (K-Ar, biotite, recalculated using IUGS recommended constants) reflects Grenvillian effects but the gneisses are much older. Krogh (1983) reported a U-Pb age of ca. 1680 Ma for similar gneisses in the southwest continuation of the Groswater Bay terrane.

Biotite granodiorite gneiss occurs in two main areas, north and east-northeast of Double Mer White Hills (Figure 2). North of Double Mer White Hills (adjacent to the Crooked River granite), biotite granodiorite gneiss is intermixed with biotite-hornblende granodiorite-diorite gneiss. Included is very sparsely megacrystic biotite granodiorite gneiss and rare muscovite-bearing granodiorite gneiss. The biotite granodiorite gneiss east-northeast of Double Mer White Hills is fine to medium grained, garnet-bearing, and gray weathering, and locally shows complex isoclinal folds.

K-feldspar augen granodiorite is interpreted to underlie an arcuate area in the eastern part of the region. The rock is homogeneous apart from a few indistinct, concordant quartzofeldspathic veins and amphibolite enclaves. K-feldspar megacrysts have been flattened and recrystallized to ellipsoidal aggregates.

Biotite granite gneiss is present east of the K-feldspar augen granodiorite. It is a medium grained rock containing minor garnet and, like the adjacent K-feldspar augen granodiorite, it is intensely foliated and lineated.

The muscovite-biotite granite gneiss, which underlies a large part of the south-central map area, is a fine to coarse grained, pink weathering rock with biotite schlieren, amphibolite enclaves and pegmatitic segregations. Locally extensive, homogeneous patches of pegmatitic muscovite-biotite-garnet granite are present, which may represent melt which crystallized after the peak of deformation.

The larger of two foliated to gneissic plutons in the Groswater Bay terrane is a pyroxene-bearing quartz syenite to granite recognized during reconnaissance mapping (Eade, 1962; Stevenson, 1970). Its outline has been refined during remapping (see also Erdmer, 1983). Rock types include quartz syenite, granite and alkali feldspar granite, with quartz monzonite and muscovite granite in western and northern border areas respectively. Pyroxene is characteristic, but other mafic minerals include garnet, amphibole and biotite. The rock was originally coarse grained but has been recrystallized to a medium grained texture, especially in gneissic borders of the pluton. Krogh (1983) obtained an age of 1632 ± 7 Ma (U-Pb, zircon) from the pluton, south of the present map area.

The muscovite-bearing granite is a medium to coarse grained, massive to strongly foliated rock which also contains garnet and biotite. The borders were not observed, and the surrounding granite gneiss may be merely a more deformed equivalent.

Lake Melville Terrane

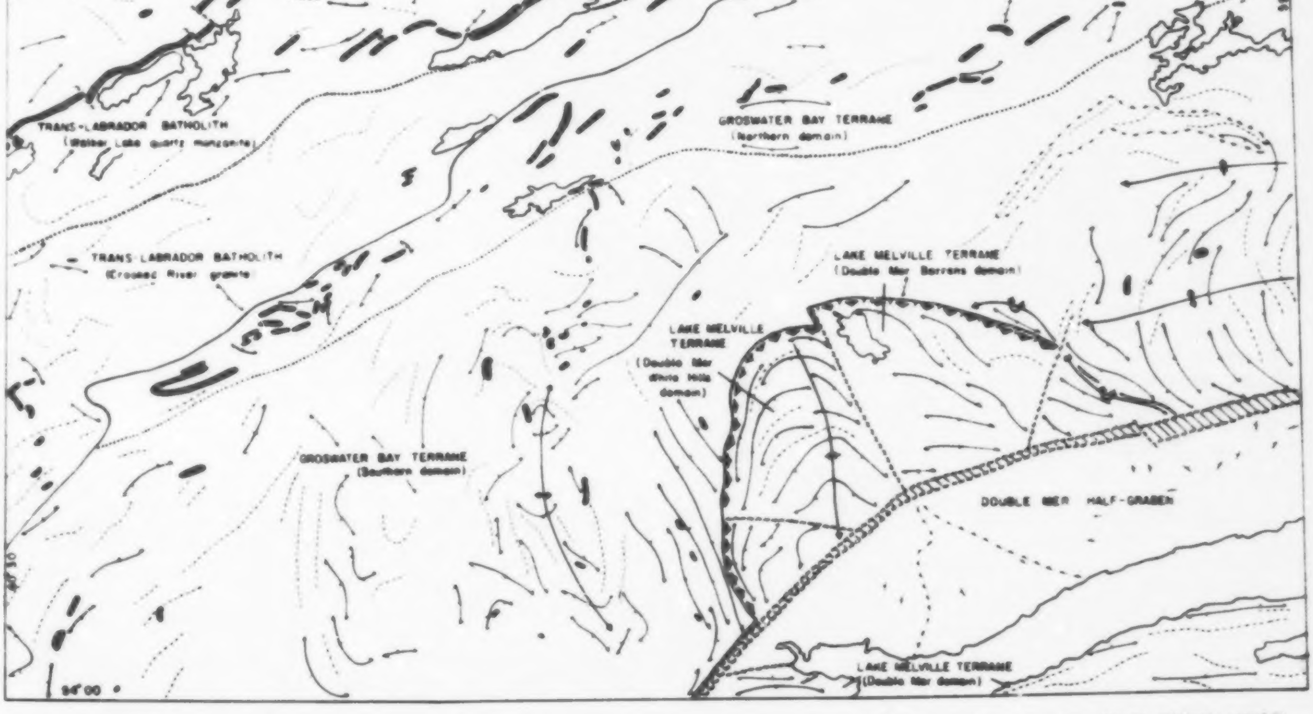
Paragneiss within the Lake Melville terrane occurs as two south dipping sheets underlying the Double Mer White Hills, and in a third area at the western end of Double Mer. The structurally lower paragneiss sheet, around the west and north flanks of Double Mer White Hills, has more variability than other paragneisses within the map area, because of a higher proportion of calc-silicate rock and quartzite to semipelite. The semipelitic schist and gneiss is characteristically well banded, with abundant kyanite, K-feldspar and garnet. The associated calc-silicate rocks are medium grained, with an alternating green and red banded appearance, due mainly to variation in pyroxene and garnet proportions. Quartzite layers are white or gray weathering and medium grained; both orthoquartzite and impure psammitic quartzite are present.

Paragneiss in the upper sheet comprises ocherous weathering psammitic gneiss with subsidiary pelite and calc-silicate rock. The pelitic rocks differ from those in the lower sheet in having sillimanite- rather than kyanite-bearing assemblages. The garnets are pale mauve, as characteristic of high grade paragneiss.

The small area of paragneiss at the west end of Double Mer is characterized by extensive leucosome, biotite schlieren, mauve garnet, variable grain size and marked compositional contrast between individual layers. Some of the rocks are diatexite. Sillimanite was tentatively recognized at one locality and confirmed identifications have been made in contiguous areas to the southeast.

Apart from granitic gneiss, most of the orthogneiss rock types described for the Groswater Bay terrane are not present in the Lake Melville terrane of the map area, but are known in Lake Melville terrane elsewhere (Gower, Gillespie et al., 1983; Gower, Noel et al., 1983). Granitic gneiss in the Double Mer Barrens domain (Figures 2 and 3) is interlayered with monzonite-granite granulite. It is a fine to medium grained rock with a strongly foliated, lineated or mylonitic fabric and contains minor garnet and (?)pyroxene. The rock may be simply a lithological variant of the monzonite-granite granulite rather than analogous to other granitic gneisses in the region. Granitic gneiss at the west end of Double Mer is mostly fine grained, homogeneous microgranite closely associated with paragneiss and diatexite. It is possible that this granitic gneiss was derived from a psammitic protolith. Similar rocks are more widespread south of the map area and a comprehensive description is given by Erdmer (1983).

Five units have been grouped as foliated to gneissic plutons in the Lake Melville terrane. These are, (i) granulite facies, pyroxene-bearing diorite to gabbro,



96°30
54°00
TRANS-LABRADOR BATHOLITH
(Walker Lake quartz monzonite)
GROSWATER BAY TERRANE
(Northern domain)
TRANS-LABRADOR BATHOLITH
(Crooked River granite)
LAKE MELVILLE TERRANE
(Double Mer Barrens domain)
LAKE MELVILLE TERRANE
(Double Mer White Hills domain)
GROSWATER BAY TERRANE
(Southern domain)
DOUBLE MER HALF-GRABEN
53°30
LAKE MELVILLE TERRANE
(Double Mer domain)
59°00
Gabbro, leucogabbro, amphibolite
Fault breccia zone
Fault
Thrust, inferred
Thrust, existence uncertain
Generalised foliation
Antiform
Synform
Aeromagnetic lineament
Bedding
Major magnetic anomaly, tick on low side
Domain boundary
Terrane boundary

Figure 3: *Lithotectonic terranes, domains and other structural features in the Double Mer White Hills and surrounding region.*

(ii) monzonite-granite granulite, (iii) leucomonzonite granulite, (iv) K-feldspar megacrystic biotite granodiorite, and (v) hornblende quartz monzonite to granite.

The pyroxene-bearing diorite to gabbro unit is interpreted to have been derived from gabbro, leucogabbro, anorthosite and diorite. These rocks are grouped because of their mutual association, low quartz content and lack of K-feldspar. Although it is tempting to regard these rocks as remnants of a former layered mafic intrusion, on present knowledge it is equally possible that entirely genetically disparate rocks have been included.

The monzonite-granite granulite is a medium to coarse grained rock containing orthopyroxene, clinopyroxene and abundant garnet. Most outcrops are quartz-poor/K-feldspar-rich monzonite, but the more northerly and easterly areas are underlain by quartz-rich monzonite and granite respectively. Taken at face value, Figure 2 suggests equivalence between the granulite facies quartz monzonite and K-feldspar augen gneiss within the Groswater Bay terrane. The rocks indeed have textural similarities. Stained slabs suggest compositional contrasts, however, although these may be interpretable in terms of granulite facies dehydration of biotite to give anhydrous mafic phases and additional K-feldspar. This avenue will be explored further when petrographic and chemical data are available.

The leucomonzonite granulite underlying the Double Mer White Hills occurs as two separate, lithologically similar sheets. The rocks have been thoroughly recrystallized to a fine or medium grained rock with a streaky, layered appearance, due to extreme flattening and stretching. The white weathering appearance of the rock gives a misleading impression that K-feldspar is rare, which staining has demonstrated unfounded. The rock differs from the monzonite-granite granulite farther east because of its finer grain size and much lower garnet content.

The remaining two granitoid units occur at the west end of Double Mer. The K-feldspar megacrystic biotite granodiorite contains elliptical megacrysts up to 8 cm long. This unit correlates with a K-feldspar megacrystic granodiorite sheet farther east mapped by Erdmer (1983) on the south side of Double Mer. The hornblende quartz monzonite to granite is a coarse grained, homogeneous monzonite to granite observed at one locality. It is lithologically comparable to much larger bodies on the southeast side of Lake Melville (Gower, Noel et al., 1983).

Mafic Intrusions

Mafic intrusive rocks within the map area are discussed with the following two considerations in mind.

(i) Although it has been recognized that mafic intrusive rocks were emplaced at various times in the Grenville Province of eastern Labrador (Gower et al., 1981; Gower, Owen and Finn, 1982; Owen and Rivers, 1983), it is rarely possible to assign a particular outcrop to a particular intrusive pulse. For this reason, mafic intrusions are not subdivided on the map, and have been collectively grouped as Helikian in age. Nevertheless, two periods of mafic activity at ca. 1650-1600 Ma (*cf.* Adlavik Intrusive Suite) and ca. 1400 Ma (*cf.* Michael gabbro) appear to be of major significance compared to the others (Gower and Owen, in preparation).

(ii) Mafic intrusive rocks, with some exceptions, show a progressive increase in deformation and/or metamorphism southeastward across the map area.

Within the Walker Lake quartz monzonite, mafic rocks fall into two main groups, both of which are assigned as Michael gabbro. These are a northern, continuous sheet and a southern discontinuous sheet. The northern sheet is a coarse grained, massive olivine gabbro without coronite textures or garnet. K-feldspar is a common interstitial phase. The southern gabbro is mineralogically and texturally similar, but it occurs as a series of elongate, discontinuous bodies. Rarely, double coronas are present (an inner corona of hypersthene and an outer corona of pargasitic amphibole; see Emslie, 1983), and a few rocks contain scattered garnet.

Gabbroid rocks are less abundant in the Crooked River granite. The three mafic bodies closest to the northern border of the Crooked River granite are biotite-bearing amphibolite, locally with relict ophitic textures. In view of the fact that most of the surrounding rocks are only slightly metamorphosed gabbros, these rocks may be the product of an earlier metamorphic event, perhaps related to neither the 1650-1600 Ma suite nor the 1400 Ma gabbros. A cluster of three mafic bodies in the south-central part of the Crooked River granite has very coarse 'appinitic' textures, a feature characteristic of the 1650-1600 Ma suite.

The mafic intrusions at the southwest end of the Crooked River granite are a mixed group of ophitic textured metagabbros, locally with double coronas, grading into amphibolite, especially at intrusion margins. Garnet is present but not in coronas. This group is assigned to the Michael gabbro.

Most of the rocks in the northern domain of the Groswater Bay terrane are fine to coarse grained gabbro to leucogabbro, generally massive, with ophitic textures, and best assigned to Michael gabbro. The gabbros are olivine-bearing with well developed double coronas. Locally partial garnet coronas are present, but more typically the garnets are scattered throughout the rock or concentrated near fractures.

Mafic intrusions are much less common in the southern part of the Groswater Bay terrane. The most northerly gabbros contain double coronas and garnet; these grade southward into garnet-coronite gabbros which still retain relict ophitic textures. Some amphibolite and metamorphosed ultramafic rocks are present and, as farther north, they contrast with nearby coronite metagabbros, suggesting that they are genetically distinct. In the most southerly outcrops in the area, ophitic texture is lost, hornblende (which increases in abundance southward, together with garnet) becomes widespread, and the rocks grade into garnet amphibolite. Hence any textural distinction between the later gabbros and the supposed earlier intrusions is eliminated.

Apart from a few minor mafic intrusions, and the diorite-gabbro unit referred to above, no mafic rocks were mapped within the Lake Melville terrane in the map area. However, it should be noted that mafic intrusions do occur in the Lake Melville terrane farther east and south.

Double Mer Formation

The Double Mer Formation consists of orange, red, pink or maroon weathering, crossbedded arkose sandstone interbedded with shale and conglomerate. These rocks were first named by Kindle (1924) and subsequently mapped by Stevenson (1970). Except for a slight modification at the west end of Double Mer, the present distribution of outcrop shown differs little from that of Stevenson (1970).

Structure

The area underlain by the Trans-Labrador batholith appears to be structurally simple. The granitoid rocks are massive or show weak east-northeast trending foliation which generally dips within 5° of vertical. All shallower dips are inclined southeast. Foliation directions in the Crooked River granite are less consistent than in the Walker Lake quartz monzonite. The arcuate outline of the gabbro near the western margin of the map area implies folding which must have also affected the host granite. In both granitoid units, but especially the Walker Lake quartz monzonite, foliation is inhomogeneous with large areas of massive quartz monzonite between local foliated zones which may be accompanied by low grade alteration. This feature is attributed to regional inhomogeneous Grenvillian strain.

Faulting in two directions is inferred. East-northeast shear zones, accompanied by retrograde alteration, were identified in two places, and northwest trending faults have been interpreted to explain offsets along the northern gabbro.

An important question, especially relevant to the northern domain of the Groswater Bay terrane, is whether the isolated hills of gabbro are part of a subsurface continuous gabbro sheet, with presently unexposed areas having been eroded and covered as a result of glaciation, or else the present outcrop genuinely reflects bedrock gabbro distribution. The former interpretation was adopted by Fahrig and Larochelle (1972), and Emslie (1983), who both depicted the gabbro as anastomosing sheets. In consideration of the opposing viewpoint, the following features are noteworthy: (i) there is a decrease in topographic continuity of exposed gabbro progressively southward, (ii) there is evidence of complex folding (one fold closure has a north trending fold axis), and (iii) many gabbro bodies exposed on the shore of Groswater Bay (outside the map area) exhibit severely deformed and boudinaged margins. Therefore the distribution of gabbro on the sketch map may well reflect bedrock distribution, entertaining the hypothesis that the bodies are 'megaboudins' formed during Grenvillian deformation.

Foliation attitude in the host gneiss is variable, perhaps because many gneiss outcrops are adjacent to gabbro and therefore are influenced by the shape of the adjacent 'megaboudin.' Gneiss remote from gabbro has an east-northeast trend. The poor exposure obscures what is probably a zone of extreme complexity. It is possible that the boundary between the Groswater Bay terrane and the Trans-Labrador batholith is a thrust, a thought endorsed by Ryan (personal communication, 1983) for the comparable boundary farther southwest.

In the southern domain of the Groswater Bay terrane, foliation attitudes and distribution of rock units suggest complex structures resulting from fold interference. The interpretation advanced here is that the pre-Grenvillian structural trend was north to northeast and was subsequently overprinted by east-northeast trending Grenvillian folds.

The nature of the interface between the northern and southern domains of the Groswater Bay terrane is unknown. In the center of the map area, mafic bodies (and structures in associated gneiss) of the southern domain have a north trend. This appears to be truncated by east-northeast trends in the northern domain, which may mean that the two domains are separated by a 'structural discontinuity,' possibly a thrust.

Evidence is strong for a thrust separating the Groswater bay terrane and the Double Mer White Hills domain of the Lake Melville terrane. In addition to a sharp topographic break, structural trends in the Groswater Bay terrane are truncated by those in the Lake Melville terrane, and the Lake Melville terrane rocks exhibit intense stretching lineations, absent in contiguous Groswater Bay terrane gneisses.

Farther east, the boundary between the Groswater Bay terrane and the Double Mer Barrens domain cannot be delineated using ground features (in contrast to the remainder of the Groswater Bay terrane - Lake Melville terrane interface in Figure 1). However, as the boundary elsewhere includes metamorphic as well as structural contrasts, it is hoped that this problem can be clarified after petrographic studies. In Figure 3, the boundary is partly indicated as a thrust and partly located along the axial trace of an interpreted recumbent synform.

The Lake Melville terrane south of Double Mer is characterized by well defined, east trending foliations, variable dip directions and small scale isoclinal folds.

The area underlain by the Double Mer Formation is interpreted as a half-graben, bounded on the north by a major fault. The fault is indicated by brecciated, sheared and mylonitized rocks, low grade alteration, a marked topographic scarp and contrasting aeromagnetic patterns. The 'fan' of three faults on the north side probably is a related structure, perhaps formed in response to the change in trend of the Double Mer fault. The presence of both mylonite and low grade alteration/brecciation suggests that the Double Mer Fault was the site of a pre-existing thrust, which was reactivated as a normal fault when the Double Mer half-graben was formed.

The southern contact between the Double Mer Formation and the underlying gneiss is unexposed. If it is a fault, it is certainly not of comparable magnitude to the fault along the northern contact. Aeromagnetic patterns suggest a north sloping base for the Double Mer Formation. An aeromagnetic high near the west end of Double Mer (Figure 3) is interpreted as a basement culmination. Bedding directions in the Double Mer Formation dip away from this high; whether this reflects folding or a pre- Double Mer Formation erosional irregularity is unknown.

Metamorphism

The Trans-Labrador batholith is characterized by greenschist facies assemblages. Epidote alteration of plagioclase and chloritization of biotite are widespread. No garnet was observed in either the Walker Lake quartz monzonite or the Crooked River granite, but Ryan (personal communication, 1983) has noted small garnets in thin sections of Crooked River granite further west. In the granitoid rocks in the Groswater Bay terrane, garnet is more abundant in the south than the north. Some of the dioritic gneisses bear scapolite. Epidote is widespread. The monzonite to granitoid rocks in the Lake Melville terrane north of the Double Mer fault contain common garnet and ortho- and clinopyroxene. In contrast, granulite facies assemblages were noted south of Double Mer.

The metasedimentary gneiss shows a concomitant increase in metamorphic grade in a southeastward direction. Muscovite-bearing assemblages are displaced by kyanite + K-feldspar and then sillimanite + K-feldspar assemblages.

Metamorphic variations in mafic rocks can be summarized as follows. In the northwest, the mafic rocks have entirely igneous mineral assemblages. The first change is the sporadic occurrence of garnet, the distribution of which can be related to avenues of fluid access (i.e. shear zones, fractures and pegmatites). Farther south metagabbro exhibits orthopyroxene - pargasitic amphibole double coronas, and garnet is more common. The garnet at this stage is not necessarily in coronas. There is a progressive change southward to mafic rocks with garnet coronas and common hornblende. The metagabbros retain ophitic textures, except at the southern margin of the map area where some rocks are amphibolite.

Economic Mineral Potential

A thorough assessment of the economic mineral potential of the area has never been undertaken, due in part to inaccessibility and to very poor outcrop. The area was included in reconnaissance mineral exploration by British Newfoundland Corporation Ltd. (BRINCO) (Beavan, 1954, 1955; Morrison, 1957) but results proved unrewarding. However, these surveys entailed very rapid coverage of extremely large areas prior to the availability of geological mapping, geophysical or geochemical data; therefore assessments made, in my opinion, can no longer be regarded as reliable.

More recently, extensive uranium and molybdenum mineralization has been found (BRINEX Ltd.) in the upper Aillik Group, in particular the Michelin uranium deposit, located only 8 km north of the present map boundary. Furthermore, uranium mineralization has been discovered (Kerswill and McConnell, 1982) and prospected by Northgate Exploration Ltd. in the Double Mer area, 9 km south of the map area. Thus an additional objective of this study was to determine the relationship between these two areas by examining the intervening ground.

The mineral potential of the area has been further assessed during this project using three approaches, namely (i) background radioactivity, (ii) lake sediment geochemical anomalies, and (iii) mineral occurrences. A scintillometer survey carried out showed that total counts on bedrock decrease from northwest to southeast. The highest values coincide with the Trans-Labrador batholith. This pattern cannot be totally explained by potassium abundance; otherwise higher values would be expected over the monzonites of the Lake Melville terrane.

Lake sediment geochemical anomalies (Geological Survey of Canada / Newfoundland Department of Mines and Energy, 1978) can be divided into two groups. Ni, Co and Fe (locally with Cu and Zn) anomalies are adjacent to mafic intrusions and are unlikely to be of real economic interest. Perhaps more important are U and Mo anomalies (locally also with Cu and Zn), which correlate with areas known, or inferred, to be underlain by paragneiss, or associated muscovite-bearing plutonic rocks.

Three mineral occurrences were located during mapping. The northern pyrite occurrence (Figure 2) and the malachite locality are quite minor, but it is interesting to note that lake sediment Cu anomalies were detected near both. Nevertheless, the lake sediment geochemistry cannot be relied on to detect all mineral occurrences. For example, the southern pyrite locality is by far the largest, having several pyritic layers up to 50 cm thick and locally containing up to 15% (guestimate) sulfide, but no lake sediment anomaly has been reported. In this case, no suitable lakes exist down-drainage for sampling.

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THE MINERAL POTENTIAL OF PARAGNEISS IN THE GRENVILLE PROVINCE IN EASTERN LABRADOR

by

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Abstract

Recent reconnaissance geological mapping, and follow-up of regional geochemical lake sediment sampling have resulted in the discovery of several U, Mo and Cu mineral occurrences in the Grenville Province of eastern Labrador. Mapping has demonstrated that these and previously documented occurrences are mainly associated with belts of pyritic paragneiss, especially in the Lake Melville terrane. This observation, combined with available reconnaissance geochemical and geophysical data, should contribute to a more focused approach to mineral exploration in the region.

Introduction

The Grenville Province in Labrador traditionally has been considered unattractive for mineral exploration. The reasons for this appear straightforward: (i) difficulty of access, (ii) poor exposure, (iii) inadequate geological, geophysical, geochemical and mineral occurrence data, and (iv) the lack of well defined targets or metallogenic models providing a focus for mineral exploration programs.

The purpose of this communication is to outline details of mineral occurrences in the Grenville Province in eastern Labrador, many of which were found during recent 1:100,000 scale mapping by the Newfoundland Department of Mines and Energy. We examine how the mineral occurrences are related to available geophysical and regional geochemical data, and demonstrate correlations between mineral occurrences and rock type.

Regional Setting

The region includes parts of four major lithotectonic terranes (Figure 1). These are from north to south (i) the Trans-Labrador batholith, (ii) the Groswater Bay terrane, (iii) the Lake Melville terrane, and (iv) the Mealy Mountains Intrusive Suite. The geological characteristics of the terranes have been outlined elsewhere (Gower, 1984; Gower and Owen, *in preparation*). As mineral occurrences are largely confined to the Groswater Bay and Lake Melville terranes, the geology of these two regions is briefly summarized below.

The Groswater Bay terrane comprises tonalite/granodiorite orthogneiss, pelitic/psammitic paragneiss, K-feldspar megacrystic granodiorite, diorite, pyroxene-bearing granitoid intrusive rocks, and mafic rocks of various ages. The Lake Melville terrane contains similar rock types, in different proportions. Paragneiss is more extensive in the Lake Melville terrane, and includes minor quartzite, marble and calc-silicate layers. Mafic rocks are less common, except near the northern flank of the Lake Melville terrane. North-northeast structural trends in the Groswater Bay terrane reflect a pre-Grenvillian fabric modified in part by east-northeast Grenvillian fabrics. Metamorphic grade increases southeastward across the Groswater Bay terrane from greenschist to middle amphibolite facies. The northern margin of the Lake Melville terrane is characterized by granulite facies assemblages which grade southward into middle amphibolite facies rocks. The oldest rocks of both terranes appear to be older than approximately 1700 Ma. The terranes have undergone several periods of deformation, metamorphism and intrusion, and were juxtaposed in their present configuration by ductile thrust faulting of probable Grenvillian age.

After the Grenvillian Orogeny, the area was affected by normal faulting, with the development of graben and half-graben in which arkose, shale and conglomerate of the Double Mer Formation were deposited.

Contribution to the Canada-Newfoundland co-operative minerals program 1982-84. Project funded by the Newfoundland Department of Mines and Energy and the Geological Survey of Canada.

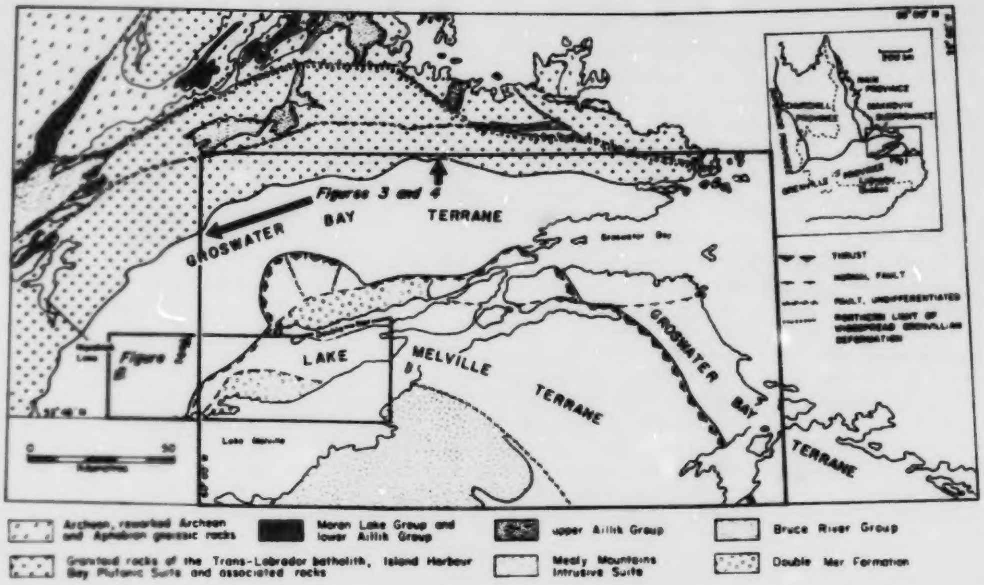

Figures 3 and 4
GROSWATER BAY TERRANE
Groswater Bay
Figure 2
LAKE MELVILLE TERRANE
GROSWATER BAY TERRANE
Lake Melville
0 50
Kilometres
GRENVILLE
THRUST
NORMAL FAULT
FAULT, UNDIFFERENTIATED
NORTHERN LIMIT OF WIDESPREAD GRENVILLIAN DEFORMATION
Archean, reworked Archean and Aphebian gneissic rocks
Moran Lake Group and lower Aillik Group
upper Aillik Group
Bruce River Group
Granitoid rocks of the Trans-Labrador batholith, Island Harbour Bay Plutonic Suite and associated rocks
Mealy Mountains Intrusive Suite
Double Mer Formation

Figure 1: *General geology of the northeastern part of the Grenville Province in Labrador, adapted from Gower and Owen (in preparation). The areas covered by Figures 2, 3 and 4 are outlined.*

Relationships Between Mineral Occurrences, Lake Sediment Anomalies and Bedrock

Uranium and Molybdenum

(i) *Mineral Occurrences*

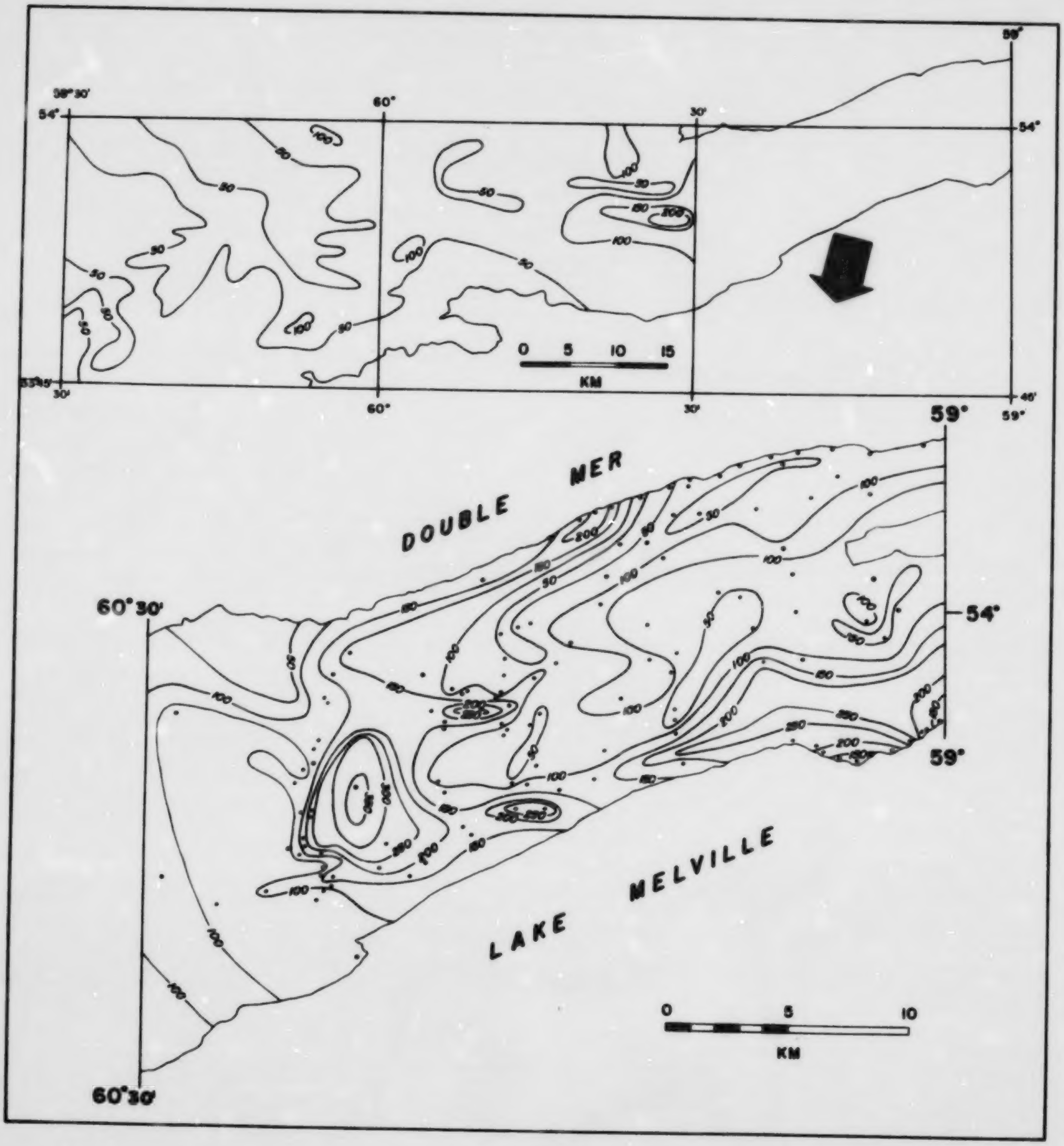
The best documented uranium mineralization is situated between Lake Melville and the southeast extremity of Double Mer, and was discovered by a Newfoundland Department of Mines and Energy field party led by J.W. McConnell in 1978. The party conducted lake sediment, lake water and airborne radiometric follow-up surveys (McConnell, 1978, 1979, 1982; Kerswill and McConnell, 1979, 1982) of lake sediment anomalies delineated by the 1977 Uranium Reconnaissance Program (U.R.P.) (Geological Survey of Canada/Newfoundland Department of Mines, 1978). Northgate Exploration Ltd. subsequently carried out sampling, trenching and geochemical surveys at the uranium showings in 1979, and proceeded with geophysical surveys and approximately 200 m of drilling in 1980 (Snow, 1980, and other unpublished assessment reports filed with the Newfoundland Department of Mines and Energy). The results of a radioactivity ground survey carried out during regional mapping in the region are shown in Figure 2.

The area received attention because, although absolute U values in lake sediment are modest compared to those found in mineralized areas elsewhere in Canada, the values are clearly anomalous with respect to much of the surrounding Grenville Province (Kerswill and McConnell, 1979).

The primary uranium-bearing mineral, uraninite, occurs within white weathering, pegmatitic leucogranite (diatexite) that is closely associated with psammitic and pelitic (sillimanite-bearing) paragneiss. The diatexite is locally tourmaline-bearing. Yellow secondary uranium staining (uranophane) is present in places. Kerswill and McConnell (1979) reported that the abundance of uraninite is directly proportional to the percentage of mafic minerals (biotite, chlorite and garnet) in the rock.

Molybdenite occurs as specks less than 0.5 cm across associated with uraninite and pyrite in the same area. A sample that gave a U analysis of 2932 g/t had a corresponding value of 464 g/t Mo (McConnell, 1978).

The locations of U and Mo mineral occurrences are shown on Figure 3. All occurrences except one Mo showing are


54°
60°
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30'
60°
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40'
59°
0 5 10 15
KM
59°
DOUBLE MER
60°30'
54°
59°
LAKE MELVILLE
0 5 10
KM
60°30'

Figure 2: *Results of a ground radioactivity survey (total counts per second on Scintrex G15-4 scintillometer) in the region between Lake Melville and Double Mer. All known U showings coincide with positive regional radiometric anomalies, which suggests that mineralization is associated with all anomalies. Dots: data stations. Modified from Erdmer (1983).*

located within the Lake Melville terrane. On the north side of Lake Melville, two U and two Mo occurrences were discovered in 1980, as was the most easterly U mineral occurrence shown on Figure 3 (Gower et al., 1981; Gower et al., 1983). All three U occurrences are located in white weathering, pegmatitic diatexite associated with sillimanite-bearing paragneiss. The mineralization was recognized by yellow or greenish yellow secondary uraniferous surface coatings which give total count scintillometer (Scintrex GIS-4) readings between 15 and 45 times background.

The two molybdenite localities immediately north of Lake Melville are minor, and associated with quartz veins in paragneiss. They do not have concomitant uranium mineralization.

The most southerly U occurrence indicated on Figure 3 was detected during an airborne gamma-ray survey (McConnell, 1978). This survey covered an area of about 600 km^2 on the south side of Lake Melville. The indicated U mineral locality is one of several in the surveyed area that gave anomalous U radiation counts (McConnell, 1978). During cursory ground examination, total count scintillometer readings of more than 5 to 10 times background were detected. The bedrock consists of quartzofeldspathic gneissic rocks but has not been examined in any detail.

The most southerly Mo mineral occurrence is regionally on strike with the last mentioned U occurrence. Mineralization consists of specks of molybdenite which were detected at a helicopter data station where the bedrock is a leucocratic, white weathering biotite granite gneiss. This is the only Mo mineral occurrence in the region where the host rock protolith was not unequivocally sedimentary. However, it should be noted that the possibility of a paragneiss host has not been excluded for either this Mo locality or the U occurrence along strike.

It appears that all the U mineral occurrences and most of the Mo localities can be related to a belt of paragneiss (now

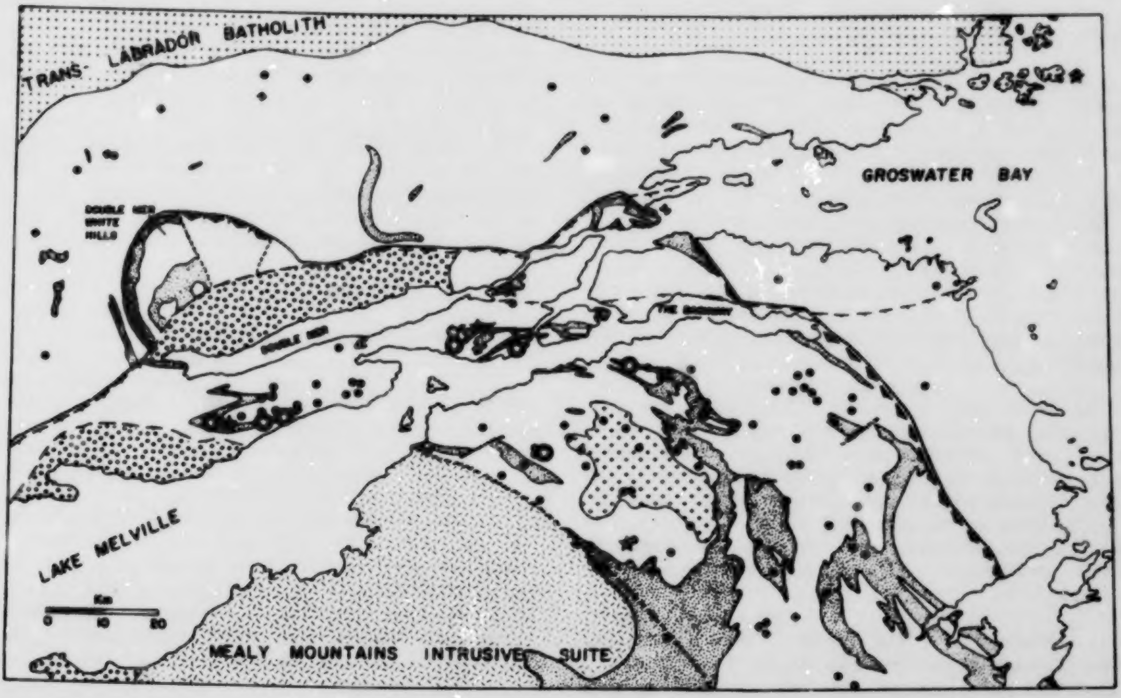

Figure 3: *Uranium and molybdenum occurrences and geochemical anomalies. Symbols: white star - uranium mineral occurrence; black str - molybdenite occurrence; black dot - lake sediment or lake water U anomaly; diamond - lake sediment Mo anomaly. Stipple pattern - paragneiss; circles - Double Mer Formation; small crosses - pyroxene quartz syenite.*

very deformed and intermixed with other rock types) that outlines an arcuate domal structure trending east-northeast near Double Mer, and southeast on the east side of the Mealy Mountains Intrusive Suite. The core of the dome is a pyroxene-bearing quartz syenite pluton (Figure 3).

One other Mo occurrence appears to be within granitoid rocks of the Trans-Labrador batholith (Figure 3). Here, the mineralization occurs within a narrow septum of pyritic sillimanite-bearing paragneiss within granitic and gneissic rocks.

(ii) Lake Sediment Anomalies

Figure 3 shows a marked concentration of U and Mo lake sediment anomalies (greater than 2 σ above mean value for the region) in the Lake Melville terrane. The anomalies are also regionally associated with known mineral occurrences. In contrast to this, the only area of interest with respect to possible mineralization in the Groswater Bay terrane appears to be an arcuate, northeast trending zone north of Double Mer White Hills. This is underlain in part by muscovite-bearing gneiss, at least some of which was derived from a metasedimentary protolith.

U and Mo lake sediment anomalies in the Lake Melville terrane do not show a close spatial association either with known mineral occurrences or with paragneiss. This can be attributed to several factors: (i) glacial redistribution of anomalous material, (ii) mapping not sufficiently detailed to define all paragneiss, (iii) additional favorable source rocks, (iv) potentially favorable areas buried beneath thick glacial till, and (v) lack of lake sediment sampling close to mineralized localities.

The dominant glacial transport direction in the region is to the east-northeast (Fulton and Hodgson, 1979). This may explain why most lake sediment anomalies between Double Mer and Lake Melville lie east of known mineralization, and is a factor to be considered in the assessment of lake sediment anomalies southeast of Lake Melville.

It should be stressed that bedrock mapping is at a reconnaissance scale only, and that many paragneiss belts have forms much more complex than shown on available maps, and, in particular, may be more extensive along strike. For example, with respect to the large cluster of U anomalies south of The Backway, it is conceivable that the tongue of paragneiss immediately southeast of the anomalies on Figure 3 extends farther north than depicted on the map. Also, paragneiss along the northeast side of the Mealy Mountains Intrusive Suite may be more extensive than indicated on the map, and may underlie the Mo locality in the area.

The outline of a pyroxene-bearing quartz syenite is included on Figure 3. No whole rock U analyses of this unit are yet available, but it is abnormally enriched in other large ion lithophile (LIL) elements; hence it may also be a source for U lake sediment anomalies.

(iii) Comment on metallogenesis

The two-stage genetic model proposed by Kerswill and McConnell (1979) for uranium in the region between Lake Melville and Double Mer appears to be applicable to other U occurrences in the Lake Melville terrane. This model is based on a concentration of uranium in the metasedimentary strata (and in some of the granite plutons) during one or several pre-Grenvillian events. The resulting "regionally" enriched strata (several times the natural crustal average) were partially melted, perhaps during several events which may include the Grenvillian Orogeny, to produce uraninite-bearing diatexite. Molybdenum mineralization, which is commonly (but not invariably) associated with uraninite in the region, may have had a similar origin.

While the several favorable paragneiss horizons in the Lake Melville terrane may have protoliths of different age, the final concentration of U (and Mo) into ore grade diatexite is probably of Grenvillian age.

Copper, Lead, Zinc, Pyrite

(i) Mineral Occurrences

Chalcopyrite, bornite, pyrite and pyrrhotite associated with malachite staining is found in both the Groswater Bay and Lake Melville terranes.

The two westerly Cu occurrences (Figure 4) in the Groswater Bay terrane are minor and are associated with muscovite-bearing schist interpreted as derived from a sedimentary protolith. Similarly, the occurrence on Black Island on the north side of Groswater Bay is associated with metasedimentary rocks.

In contrast, the other three Cu occurrences in the Groswater Bay terrane are adjacent to mafic intrusions, as are the pyrite occurrences in the same region. The two Cu occurrences on the north side of Groswater Bay were discovered by BRINEX Ltd. (Kirwan, 1960). Grab samples from one locality gave Cu values of 0.25% and 0.30%, and one from the other locality has 1.4% Cu.

In the Lake Melville terrane, Cu mineralization occurs in a belt that is roughly parallel to the Rigolet thrust zone. Three general observations can be made: (i) this belt correlates with a zone of granulite facies rocks, (ii) Cu mineralization in the Lake Melville terrane is separate from U and Mo mineral occurrences, and (iii) with two possible exceptions, Cu mineralization is associated with paragneiss.

The first two observations may be interdependent, in that granulite facies rocks are commonly depleted in LIL elements.

Within paragneiss, the Cu mineralization commonly is accompanied by broad pyritic zones. For example, the most northerly Cu mineral locality in the Lake Melville terrane is associated with a concordant pyritic layer more than 3 m wide. Pyritic zones, associated with traces of Cu mineralization, are also extensive at the south end of Sandwich Bay. The Cu locality at Eagle River was first reported by Douglas (1953), who described the mineralization as being a 70 cm wide band in a quartzitic layer about 4 m across, traceable along strike for more than 30 m. A grab sample from this locality contains 2.8% Cu (Douglas, 1953). BRINEX Ltd. carried out stream sediment and airborne magnetic and EM surveys in the area in 1965 (Sutton, 1965) and conducted follow-up drilling of the Eagle River showing in 1966. Five holes were drilled for a total length of about 80 m (Sutton, 1966). Samples were analyzed for Cu, Au and Ag but results were not encouraging. Apart from this locality, we are unaware of any Au analyses for the region.

The only Cu mineral occurrence in the Lake Melville terrane that is clearly not associated with metasedimentary rocks is located at the east end of The Backway, where the host rock is metagabbro.

A large pyrite showing without known Cu mineralization occurs in the Double Mer White Hills. Several pyritic layers are present, some exceeding 50 cm in thickness, with a strike length of more than 50 m.

Lead and zinc mineralization was found on the north side of Double Mer, 11 km west of Rigolet. Galena, sphalerite and chalcopyrite are associated with quartz and calcite in a vein 1 m across and 10 m long. One sample gave values of 0.36% Pb and 2.5% Zn (Halet, 1946).

(ii) Lake Sediment Anomalies

Most of the Cu lake sediment anomalies are in the Groswater Bay terrane. Apart from two anomalies in the western part of this terrane, which can be correlated with known Cu-mineralized muscovite-bearing schist, there is no obvious correlation with metasedimentary gneiss. Some of the lake sediment Cu anomalies in the Groswater Bay terrane are associated with high Co or Ni values in lake sediment and, hence, probably relate to material derived from mafic rocks.

A major Pb and Zn lake sediment anomaly was delineated 2 km west of Rigolet during the 1977 U.R.P. survey. Its close proximity to this settlement casts doubt on its significance (as it may have resulted from local contamination), but high Pb and Zn values exist elsewhere in the district and show a spatial association with areas underlain by quartz diorite (which is also the host rock for the known Pb-Zn mineralization). High Pb and Zn values are associated with similar quartz diorite south and east of Cartwright (mostly outside the area shown in Figure 4).

(iii) Comments on Metallogenesis

Cu mineral occurrences in the region are associated with two rock types, paragneiss and mafic intrusive rocks. Stratabound Cu mineralization in sedimentary rocks occurs in a variety of associations. However, any attempt to associate mineralization in the Grenville Province with specific sedimentary environments is unrealistic, for two principal reasons: (a) no specific study has been made of the mineralization or host rocks, (b) the mineral occurrences are in granulite facies rocks which opens to question detailed protolith identification.

Cu mineral occurrences associated with gabbro are accompanied by pyrite and pyrrhotite. Their localization at gabbro-gneiss contacts probably results from concentration of sulfides in a relatively low stress local environment during metamorphism.

Conclusion

The empirical observation that mineralization is closely associated with paragneiss, and the recent delineation of areas underlain by paragneiss in the Grenville Province of eastern Labrador, should contribute to a more focused approach to mineral exploration in this region. Identification of the mineral occurrence - host rock association, combined with the

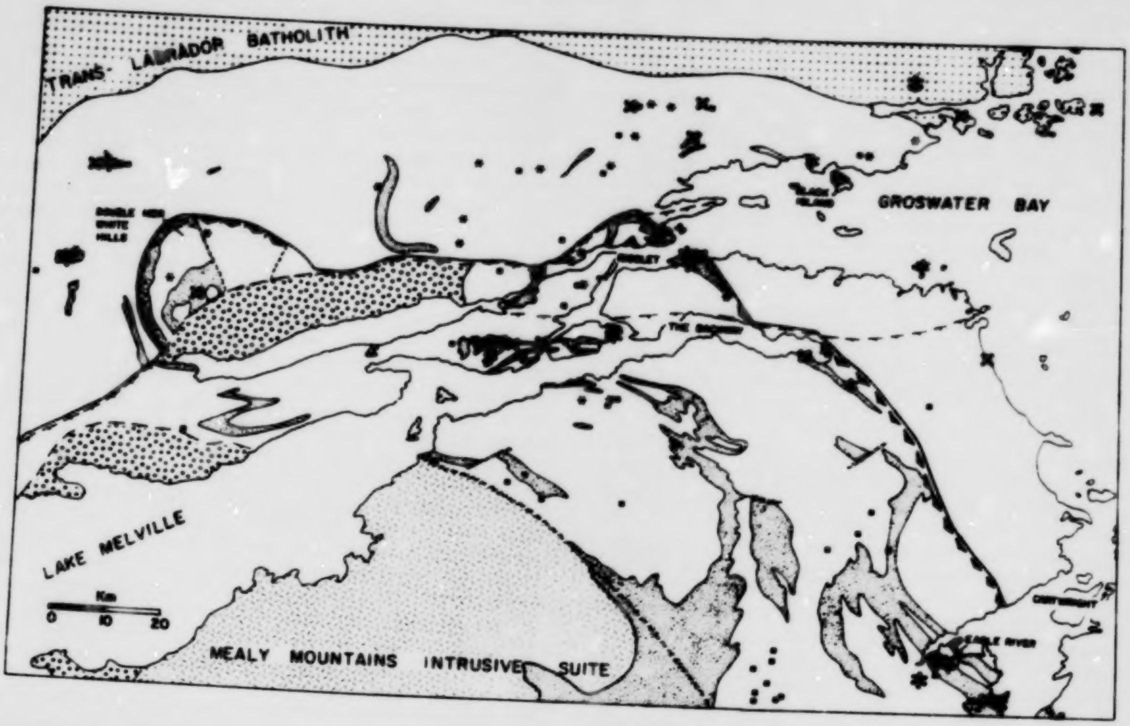
TRANS-LABRADOR BATHOLITH
DOUBLE MER WHITE HILLS
BLACK ISLAND
GROSWATER BAY
RIGOLET
THE BACKWAY
LAKE MELVILLE
Km
0
10
20
MEALY MOUNTAINS INTRUSIVE SUITE
CARTWRIGHT
EAGLE RIVER

Figure 4: *Copper, pyrite, pyrrhotite and lead and zinc mineral occurrences and geochemical anomalies. Symbols: large asterisk - copper mineral occurrence; small asterisk - Cu lake sediment anomaly; cross - pyrite and/or pyrrhotite occurrence; large square - lead-zinc mineral occurrence; small square - Zn lake sediment anomaly. Other symbols as in Figure 3.*

use of available reconnaissance geochemical and geophysical data will assist in the identification of new exploration targets.

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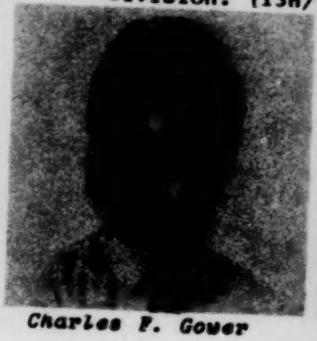

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COASTAL LABRADOR AGGREGATE RESOURCE PROJECT

by

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Introduction

1983 marked the beginning of aggregate resource inventory mapping in the coastal areas of Labrador.

The initial phase of the program included field sampling in communities from Lodge Bay to Rigolet. The project was conducted in a similar pattern to the Inventory of Aggregate Resources Program, which completed sampling within a 6 km wide corridor study area along all existing and proposed transportation routes in Newfoundland and Labrador.

Objectives

Aggregate deposits of sand, gravel, stone, etc. suitable for construction purposes are a finite nonrenewable resource. The present need in Labrador for data on these deposits is considered to be even greater than it was in Insular Newfoundland because of the lack of available information or mapped data in Labrador, and the general lack of overburden and granular materials.

By completing a mapping program of this nature, we hope to aid community development and help prepare communities for future expansion.

We plan to identify sources of sand and gravel as well as carry out field and laboratory analyses. This range of analysis is considered essential for proper resource management, i.e. to identify high grade materials that should not be used for subgrade (ballast or fill) construction and reserved for future road topping or concrete uses in local communities.

In cooperation with municipal or community councils, we plan to delineate resource sites and have them protected by zoning on the municipal plans.

The project involves locating and detailed sampling of any aggregate reserves in the proposed areas. In areas lacking quality grade aggregates, alternative sources such as till with a low silt/clay content and/or suitable bedrock are assessed in regards to current and future local needs. The designation of the aggregate resources as extraction areas within specific locations will ensure that aggregates can be preserved to meet the present and future demands of the domestic and commercial aggregate consumer. After the aggregate resources reserves are depleted, quarry areas are to be rehabilitated to a state suitable for other proposed uses and the area moved from the extraction designation.

Other objectives of the project are to identify surface landforms, with particular emphasis on determining areas suitable or unsuitable for a variety of purposes such as hydrogeological formations for screened or drilled wells and for various community needs (e.g. housing, recreation, roads or servicing, etc.). Geotechnical properties of the subsoil, overburden and bedrock materials will be identified to assist preengineering studies of route selection for roads or water or sewage mains.

Field Work, 1983

Field work involved sampling of overburden materials, with particular emphasis on materials suitable for construction purposes; particular attention was given to problem or hazardous areas. In addition, terrain analysis identified areas most suited for municipal services and residential development.

Field work was concentrated around the coastal communities of Mary's Harbour, Fox Harbour, Lodge Bay, Black Tickle, Charlottetown, Williams Harbour, Paradise River, Port Hope Simpson, Rigolet and Cartwright. Some reconnaissance work was also conducted at Battle Harbour, Batteau, Domino, Pinsent Arm and Spotted Island.

Field work involved extensive foot traverses to sample and accurately delineate zones of aggregate potential previously identified by aerial photographic interpretation. Helicopter and boat traverses were done in areas inaccessible by foot traversing. Approximately 200 samples were collected for particle size analysis and lithological investigation.

Project funded by the Newfoundland Department of Mines and Energy and the Canada Department of Regional Economic Expansion (Coastal Labrador Subsidiary Agreement).

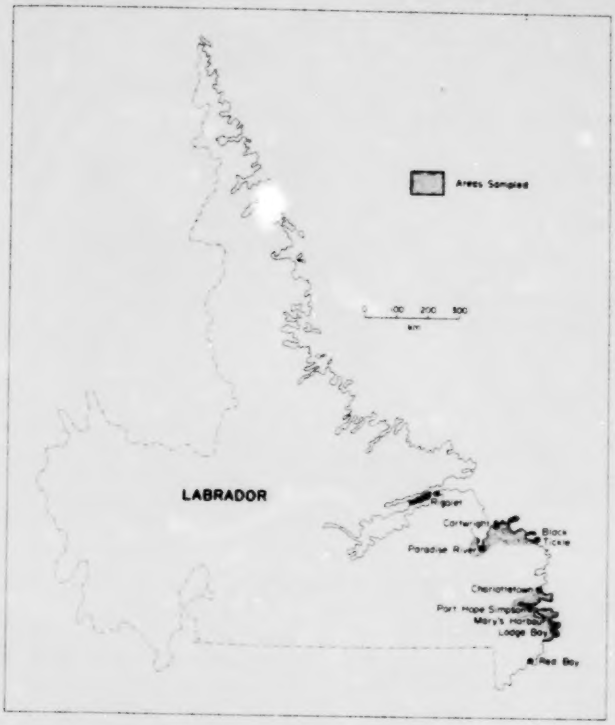

Figure 1: *Detailed aggregate resources, coastal Labrador.*

Mapping was normally conducted at a scale of 1:50,000, although 1:25,000 maps were used in some areas.

Office Program

During the winter of 1983-84, sample analyses will be done and maps compiled. This will include the production of two sets of 1:50,000 scale maps, consisting of approximately 15 maps each. One series of maps will include sample localities and zones of aggregate potential; the other series will show landform classification.

Work will also be started on two sets of 1:250,000 scale maps consisting of 3 maps each. One set will give a summary of aggregate zones as depicted on the 1:50,000 maps; the other 1:250,000 scale map set will give a summary of the bedrock geology with emphasis on the geotechnical aspects of bedrock, including marginal notes on each map with a unified legend.

Plans

Future work (subject to Management Committee approval) will include field sampling in the communities of Postville, Davis Inlet, Nain and the proposed relocation sites for Hopedale. A reconnaissance trip to these communities at the end of the 1983 field season has shown areas of aggregate potential as well as problems in some areas with regards to aggregate extraction. Davis Inlet, for example, has a sandy terrace within the community. Housing development has begun to occur at the top of this deposit. With proper mapping and sampling, this area should be designated as an area of aggregate extraction for community and local needs, to be followed later by housing development.

Acknowledgements

We thank Wayne Tuttle of Goose Bay for his logistical support.

We also thank Clarence Rumboldt Jr. in Marys Harbour, Mr. and Mrs. James Sampson in Port Hope Simpson, Daryl Vators in Cartwright and Steve Kippen in Rigolet for their hospitality and valuable advice while working in those communities.

The manuscript was reviewed by D.G. Vanderveer and M.J. Batterson.

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M.J. Ricketts

D.J. Bragg

A PRELIMINARY REPORT ON DRIFT PROSPECTING STUDIES IN LABRADOR: PART II

R.A. Klassen

Klassen, R.A., A preliminary report on drift prospecting studies in Labrador: part II; in Current Research, Part A, Geological Survey of Canada, Paper 84-1A.

Abstract

A study of glacial history and till geochemistry in east-central Labrador was continued during 1983. The last directions of regional ice flow were northeastward in the northern part of the area, and eastward to southeastward in the southern part. An earlier northward to north-northeastward phase of flow is recognized. Trace element geochemistry of clay-size and of pebble-size fractions of till is influenced by weathering (soil development). Trace metals are most abundant within the C soil horizon and decrease upward through the B and A horizons. Variations in the regional geochemistry of copper, nickel, and uranium in till generally match changes in regional bedrock type.

Résumé

L'étude de l'histoire glaciaire et de la géochimie des tills dans le centre-est du Labrador s'est poursuivie en 1983. L'écoulement régional le plus récent de la glace s'est fait en direction du nord-est dans la partie nord de la région et vers l'est et le sud-est dans la partie sud. Une phase d'écoulement plus ancienne vers le nord au nord-nord-est y est identifiée. La géochimie des oligo-éléments dans les fractions de till de la taille des argiles et des galets dépend du degré d'altération (évolution des sols). Les métaux à l'état de traces sont plus abondants dans l'horizon C et leur quantité diminue vers le haut dans les horizons B et A. Les variations dans la géochimie régionale du cuivre, du nickel et de l'uranium dans le till suivent généralement les changements dans le type de socle régional.

INTRODUCTION

The history of regional ice movement and the composition of drift in central and eastern Labrador have been studied by the Geological Survey to assist the development of drift prospecting techniques. Areas of fieldwork during 1982 and 1983 included the eastern part of Snegamook Lake (13K) and western part of Rigolet (13J) map areas (Melody Lake area), and during 1983, the eastern part of Ossokmanuan Lake (23H) and western part of Winokapau Lake (13E) map areas, (Churchill Falls area). This report refers only to results of field and laboratory work from the Melody Lake area; it expands on earlier comments by Klassen (1983) concerning ice flow directions and presents geochemical data based on analysis of samples collected during 1982.

Acknowledgments

Field assistance was capably and cheerfully provided by Mr. E. Ochs. Dr. C.F. Gower, Department of Mines and Energy, Newfoundland, provided camp logistical support and geological information concerning bedrock units and the origins of erratics, and he is thanked for his help. Mr. R. Bartlett, pilot, is thanked for his help and flying skills.

BEDROCK GEOLOGY

The study area occupies parts of the Nain and Grenville structural geological provinces and parts of the Makkovik Sub-Province. Bedrock includes a crystalline complex of gneiss, granite, and granitoid rocks of Archean to Helikian ages, and a sequence of sedimentary and volcanic supracrustal rocks of Aphebian and Helikian ages (Fig. 1). The supracrustal rocks include the Aphebian Moran Lake and Aillik groups, and the Paleohelikian Bruce River and Seal Lake groups. In the southern part, sedimentary rocks of the Hadrynian Double Mer Formation outcrop. The Proterozoic supracrustal rocks form part of the Central Mineral Belt of Labrador and are known to contain uranium and copper mineralization (Ryan, 1981, 1982a, b).

PREVIOUS WORK

Surficial materials of the study area have been mapped at 1:250 000 scale by Fulton et al. (1980a, b). Brief descriptions of ice flow directions in the Melody Lake area have been given by Vanderveer (1982) and Klassen (1983), who estimated that the last directions of regional ice flow were towards the east and southeast in the southern part of the study area and towards the northeast in the northern part. Both authors also found indications of ice flow oriented at about north to north-northeast. Klassen (1983) described erratics of sedimentary rock within the Melody Lake area derived from bedrock sources located more than 50 km to the west.

METHODS

The program of field sampling was conducted with helicopter (Bell 206) support. Sampling during 1983 was extended to the south and east of areas visited during 1982 to provide more complete coverage of the region. During reconnaissance mapping flights, landings were made to examine surficial deposits, landforms, and the evidence of ice flow directions, and till was sampled routinely for examination of clast lithology and for geochemical analysis. Throughout the study area till samples were collected at a density of about 1 per 10 000 ha for the purpose of characterizing regional variation in till composition. Samples were spaced more closely, at about 1 per 100 to 1 per 10 ha, near areas of known mineralization (eg. Michelin deposit) and areas of known mineralized erratics. Pits were dug to depths of 40-100 cm, depending on the depth to bedrock and the presence of coarse clasts, and samples were collected from the least oxidized soil horizon encountered near the base of the pit. To investigate the influence of weathering (e.g., soil development) on geochemistry, soil horizons were sampled sequentially in 15 test pits located throughout the area.

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[1] Contribution to Canada-Newfoundland co-operative mineral program 1982-84. Project carried by Geological Survey of Canada

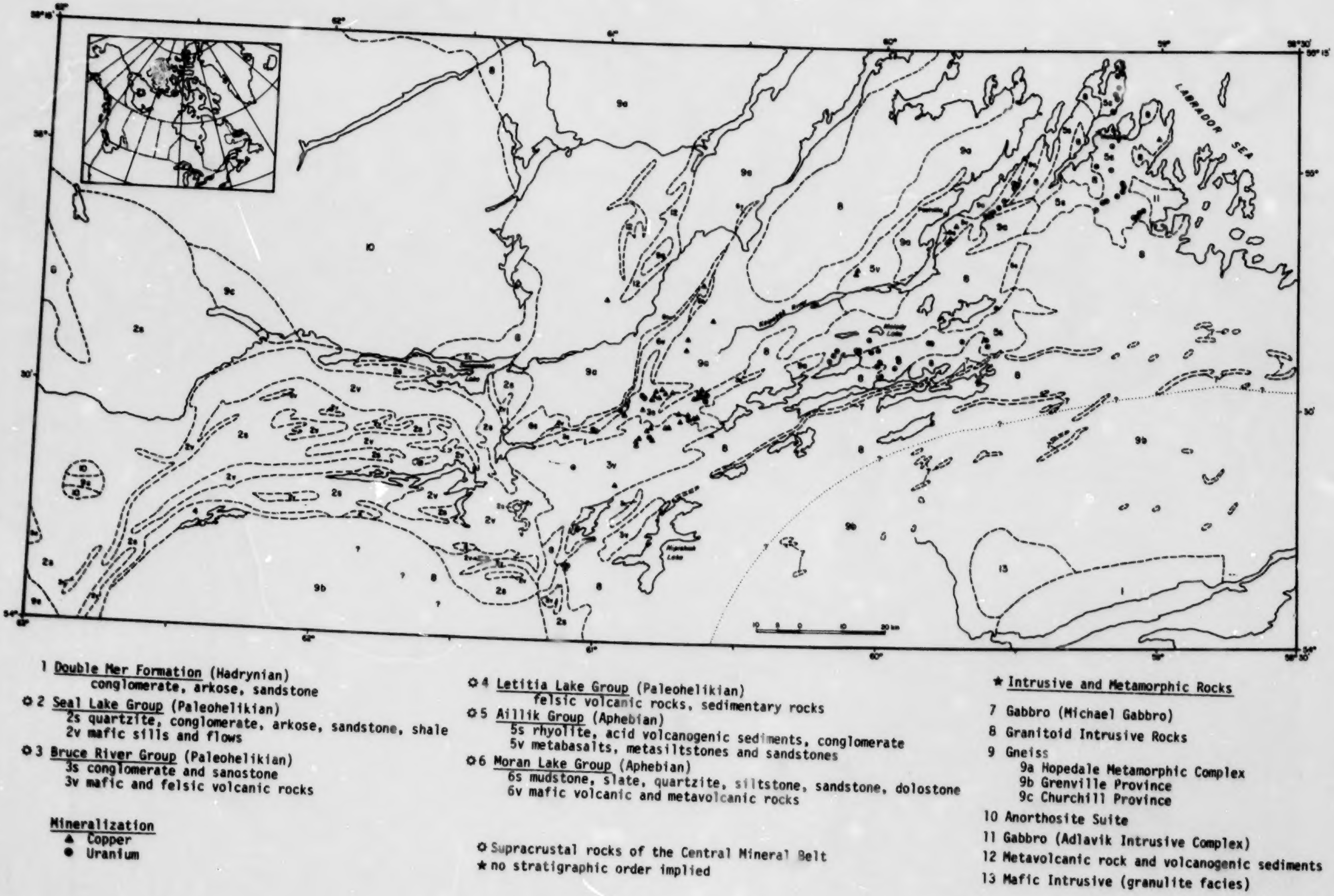
LABRADOR SEA
Melody Lake
1 Double Mer Formation (Hadrynian)
conglomerate, arkose, sandstone
2 Seal Lake Group (Paleohelikian)
2s quartzite, conglomerate, arkose, sandstone, shale
2v mafic sills and flows
3 Bruce River Group (Paleohelikian)
3s conglomerate and sandstone
3v mafic and felsic volcanic rocks
Mineralization
▲ Copper
● Uranium
4 Letitia Lake Group (Paleohelikian)
felsic volcanic rocks, sedimentary rocks
5 Aillik Group (Aphebian)
5s rhyolite, acid volcanogenic sediments, conglomerate
5v metabasalts, metasiltstones and sandstones
6 Moran Lake Group (Aphebian)
6s mudstone, slate, quartzite, siltstone, sandstone, dolostone
6v mafic volcanic and metavolcanic rocks
Supracrustal rocks of the Central Mineral Belt
★ no stratigraphic order implied
★ Intrusive and Metamorphic Rocks
7 Gabbro (Michael Gabbro)
8 Granitoid Intrusive Rocks
9 Gneiss
9a Hopedale Metamorphic Complex
9b Grenville Province
9c Churchill Province
10 Anorthosite Suite
11 Gabbro (Adlavik Intrusive Complex)
12 Metavolcanic rock and volcanogenic sediments
13 Mafic Intrusive (granulite facies)

Figure 1. *Generalized geological map of the Melody Lake study area and adjacent regions, east-central Labrador. Geology after Greene (1970), Gandhi (1978), Wardle and Bailey (1981), Gower et al. (1982), and Ryan (1981, 1982a, b).*

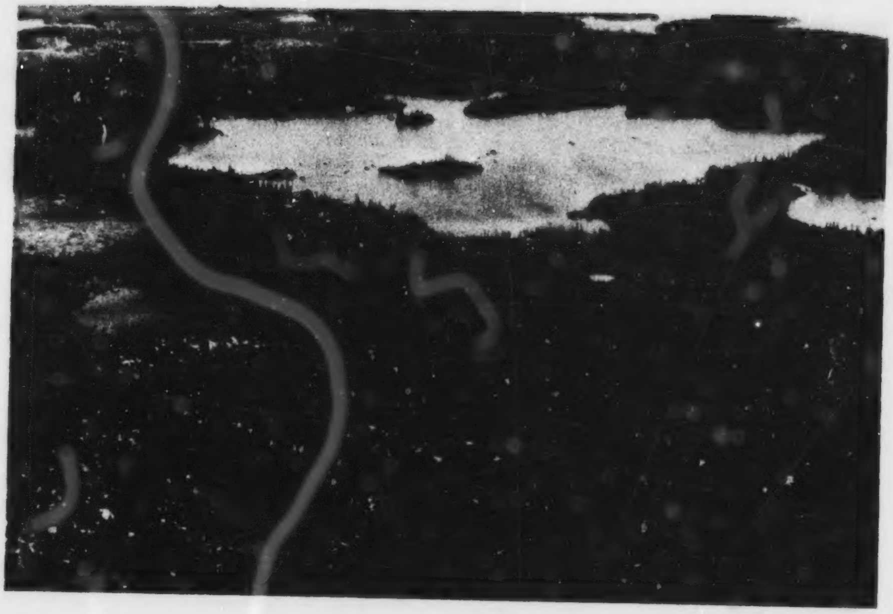

Figure 2

Bouldery ribbed moraine, shown forming a ridge oriented across the central part of the photograph between the lakes, is common within the study area. The boulders, which are large (>2 m) and form a nearly continuous cover, are most common in areas of granitoid bedrock south of Kaipokok River. Tree cover provides ground scale. (GSC 203803-I).

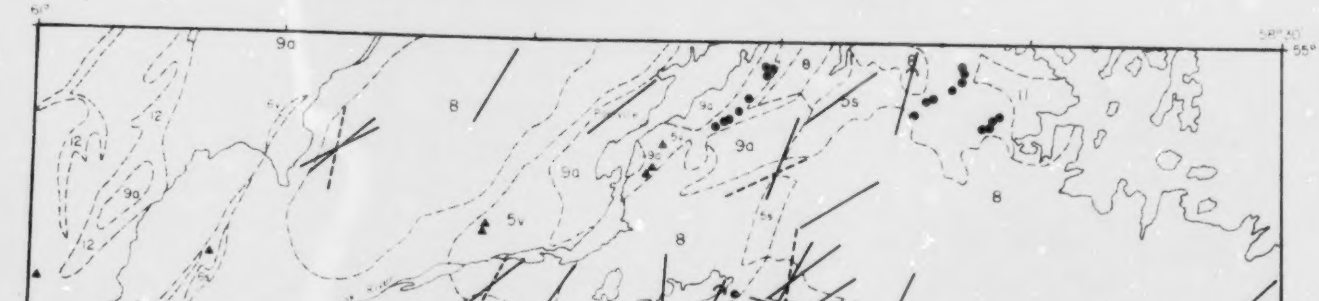
61°
58°30'
55°
30'
54°
9a
8
5v
5s
9a
11
12
8
3v
9b
7
13
1
Kaipokok River
Nipishish Lake
Ice Flow Orientation
(well defined, poorly defined)
Arrow shows sense of direction
10
5
0
10
20 km

Figure 3. *Ice flow trends, based chiefly on glacial striae. Regional ice movement was generally eastward, based on streamlined bedrock landforms. Striae trending nearly north, found at four locations, are considered to predate the last phase of regional ice flow. A magnetic declination of N32°W has been assumed for all measurements. Bedrock geology is explained in Figure 1.*

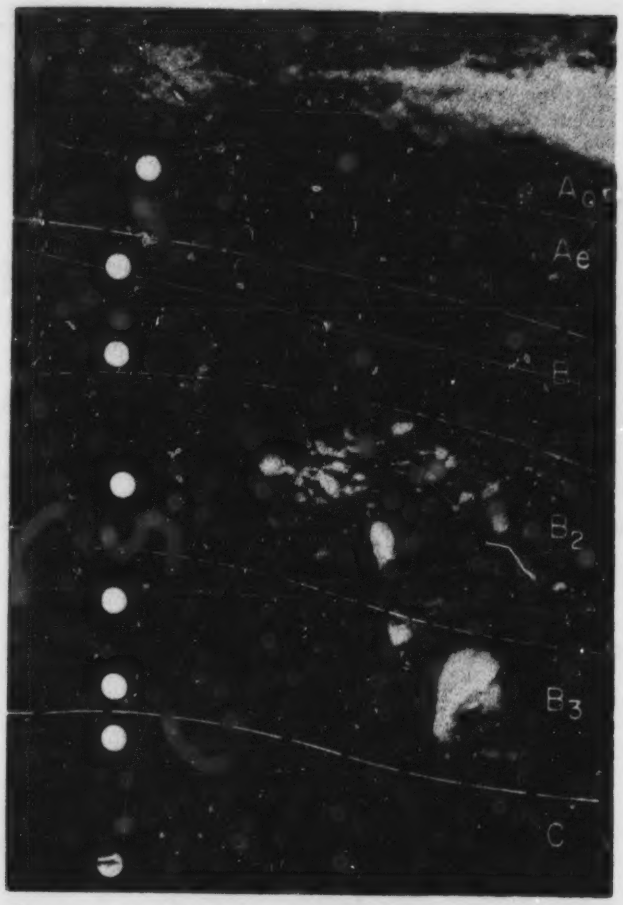

Figure 4. *Podzol-like soil profile showing the different soil horizons commonly encountered during excavation of sample pits. Samples were collected at the points marked, and their trace metal contents are given in Figure 5. (GSC 203803-P).*

The geochemical properties of till reported here are based on analysis of the clay-size (<0.002 mm) and of the pebble-size (2-4 mm) fractions. The two size fractions were chosen to compare the trace metal contents of two components of till that are considered likely to be distinct in their mineralogical and lithological makeup, and to further examine the influence of near-surface weathering. Clay is considered likely to retain elements released during weathering due to its higher content of phyllosilicate minerals and, consequently, its relatively high cation exchange capacity. Analysis for copper, lead, zinc, nickel, chromium, molybdenum, manganese, and iron was done, using atomic absorption methods, by Bondar-Clegg and Company Ltd. (Ottawa). Analysis for uranium was done using fluorimetric and delayed neutron activation methods.

RESULTS AND DISCUSSION

Surficial geology

Within the Melody Lake area till is extensive at the surface and is characteristically sandy and bouldery. In the northern part, till is thin (<2 m) to discontinuous over hilltops, and is much thicker across valley floors where it forms extensive areas of ribbed moraine (Rogen moraine) (Fig 2). In areas of granitoid rocks, south of Kaipokok River, till is dominated by large (>2 m) boulders that form a nearly continuous surface cover. Sampling of till in such areas can be extremely difficult due to the boulder cover.

In the southern part of the area, which is underlain by gneisses of the Grenville Province, till appears generally to be sandier and thicker, forming extensive areas of hummocky drift and streamlined landforms in the lee of bedrock hills. Some till deposits were found to be partially stratified, containing sand lenses and minor bedding, and are considered to have been deposited during deglaciation.

Directions of ice movement

Glacial striae vary in orientation from north-northeast to southeast within the Melody Lake study area (Fig. 3). Across the northern part of the area nearly all striae are oriented generally northeast, and across the southern part they are generally southeast to east. Because many were measured on hilltops and, in some cases, are oriented across topographic trends, the striae are thought to be the product of the last major phase of regional ice movement. Streamlined crag-and-tail landforms in the southern part (Fulton et al., 1980a) are similar in orientation to the striae reported here and indicate that ice flow was eastward towards the Labrador Sea; no evidence of flow having a westward component has been recognized.

At four separate locations striae and small grooves trending north to north-northeast, across the regional trends reported above, were observed (Fig. 3). At three of the sites the glacial markings were poorly defined and were not found within glacial polish. The fourth site was located near the coast, at the summit of Monkey Hill (elevation 700 m a.s.l.), overlooking the town of Makkovik, where all recorded striae in glacial polish trended N13°E; the streamlined form of bedrock at the summit indicated northward ice flow.

The nearly northward-oriented striae are interpreted to have been formed prior to the last regional phase of ice flow because they are not found generally within glacial polish and are poorly preserved. They indicate that a dispersal centre could have been located south to southwest of the study area during their formation. Alternatively, the ice moving eastward towards the Labrador Sea could have been turned northward within the Melody Lake area by flow from a separate dispersal centre located to the east or southeast.

With regard to the marked variations in directions of ice flow within the study area, reported above, the orientations of glacial dispersal trains could be expected to vary accordingly. Prospecting for the bedrock sources of dispersal trains requires that the regional history of ice flow be known to establish how local flow directions could have changed during the course of glaciation.

Distributions of indicator lithologies

Erratics of sedimentary rock, including red arkosic sandstone, conglomerate, and red quartzite derived from Proterozoic units west of Nipishish Lake (Fig. 1), were found as far east as the area of Postville and the western flanks of Mount Benedict. Their distribution is extended eastward of that reported by Klassen (1983) and demonstrates glacial transport distances of more than 100 km. Source areas are considered to most likely include the Seal River and Bruce River groups (Fig. 1).

Compositional evidence of early northward ice flow has not been recognized.

Till geochemistry

Soil profiles appear commonly to be Podzol-like, having a surface organic-rich Ao horizon, a bleached eluviated Ae horizon and iron-stained B_1 and B_2 horizons all of which overlie sediment without obvious weathering – the C horizon (Fig. 4). At wet, poorly drained sites, soils generally lack an eluviated horizon, the zone of iron stain is wider, and iron oxides can form a cemented (ortstein) layer.

Trace element geochemistry of till varies with the position of the sample within the near-surface zone of weathering. Among samples collected from individual soil profiles, the content of trace metals within clay is consistently greatest within the least weathered part of the profile exposed at the base of sample pits and decreases upwards to the eluviated horizon (Fig. 5). Metal concentrations within the clay-size fraction can change by an order of magnitude between the bottom and top of metre-deep pits for some of the elements analyzed. Although relative change in metal content is much greater within clay, profiles of the trace metal variation in the pebble-size fraction appear similar to those based on analysis of clay and metal concentrations decrease upward within test pits.

The geochemical differences observed within the sample pits are associated here with weathering processes and are not the result of compositional change associated with a bipartite sequence of 'basal' till and overlying 'ablation' till. Neither lithological nor gross textural change was noted within the test pits to indicate the presence of two compositionally distinct sediment types. In addition, the patterns of change in trace elements match closely those of iron and manganese which are easily mobilized and are associated with soil development.

The abundance of trace metals is not greatest within the iron-stained B horizon, contrary to the generalized profile shown by Levinson (1974, p. 98). The profiles (Fig. 5) indicate that in both size fractions, trace elements are depleted in the A and B horizons relative to their levels within sediment of the underlying C horizon. Similar trends

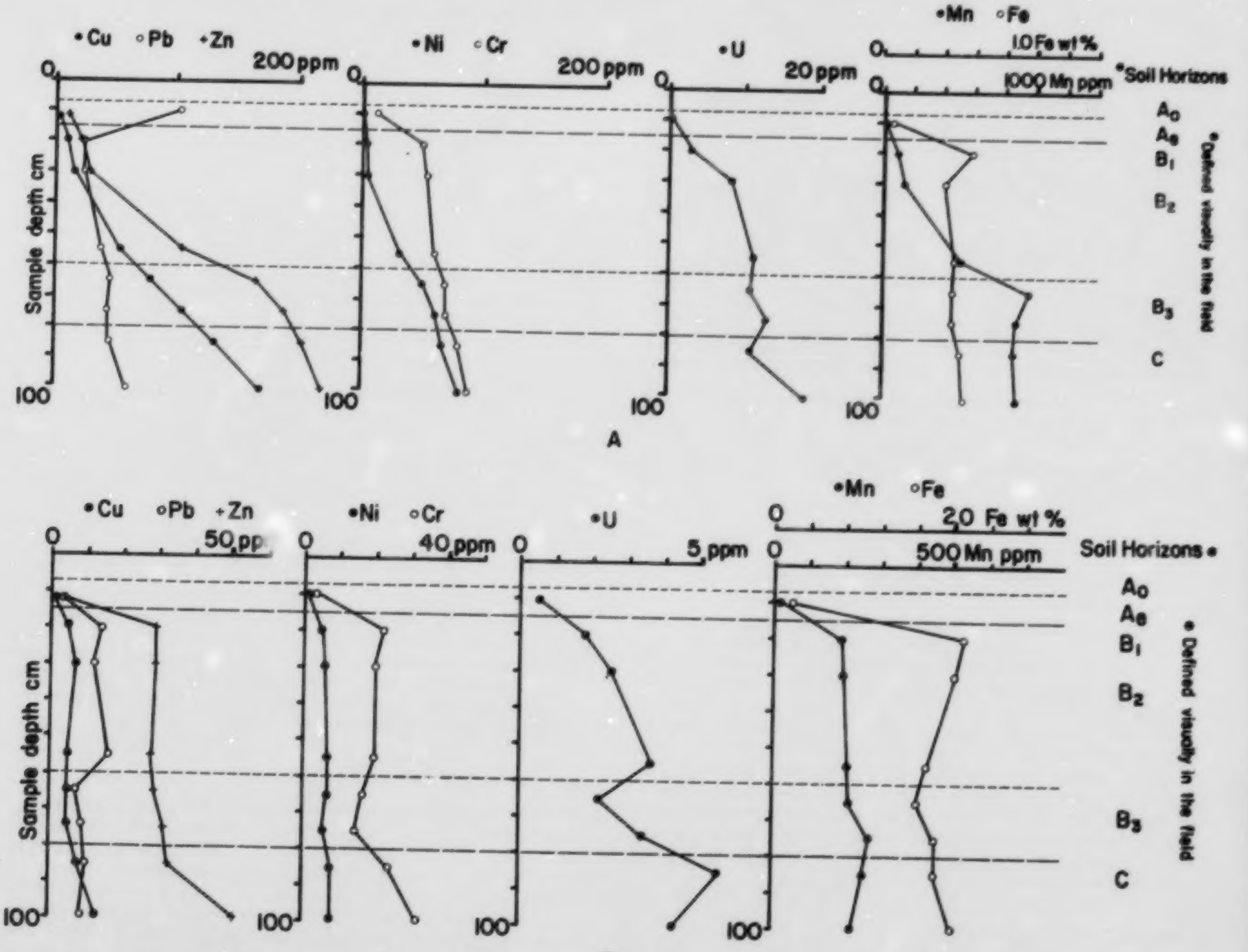

Figure 5. Trace element variation in (A) clay-size (<0.002 mm) and (B) pebble-size (2–4 mm) fractions within the soil profile shown in Figure 4. The pit was dug within a dispersal train of uraniferous erratics, and metal contents are generally greater than found elsewhere in the study area. The shapes of the trace element profiles are, however, typical.

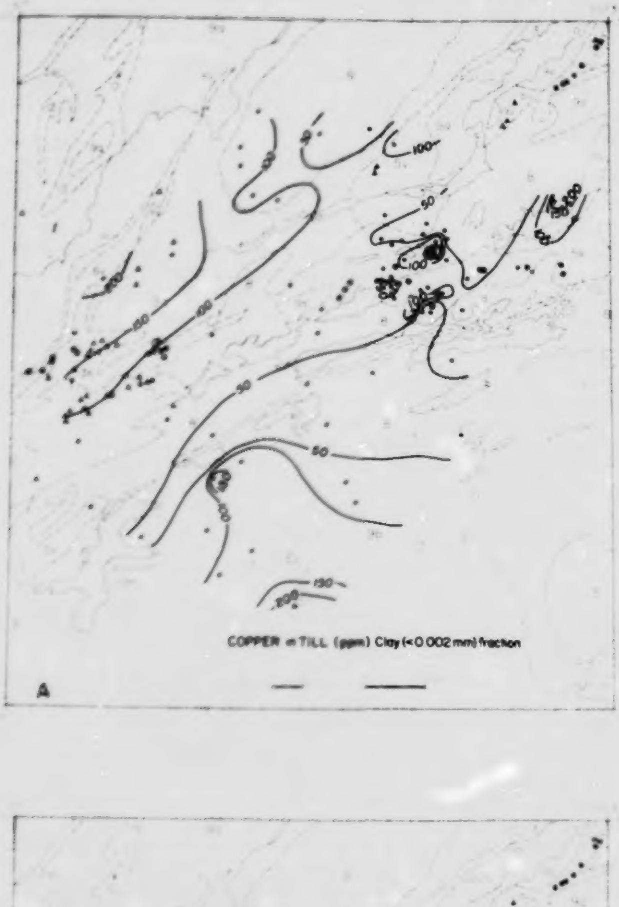
COPPER in TILL (ppm) Clay (<0.002 mm) fraction
A
100
50
150
200
COPPER in TILL (ppm) 2-4 mm fraction
B
30
10

Figure 6. *Regional variation in the copper content in the (A) clay-size (<0.002 mm) and (B) pebble-size (2-4 mm) fractions of till. Bedrock geology is explained in Figure 1.*

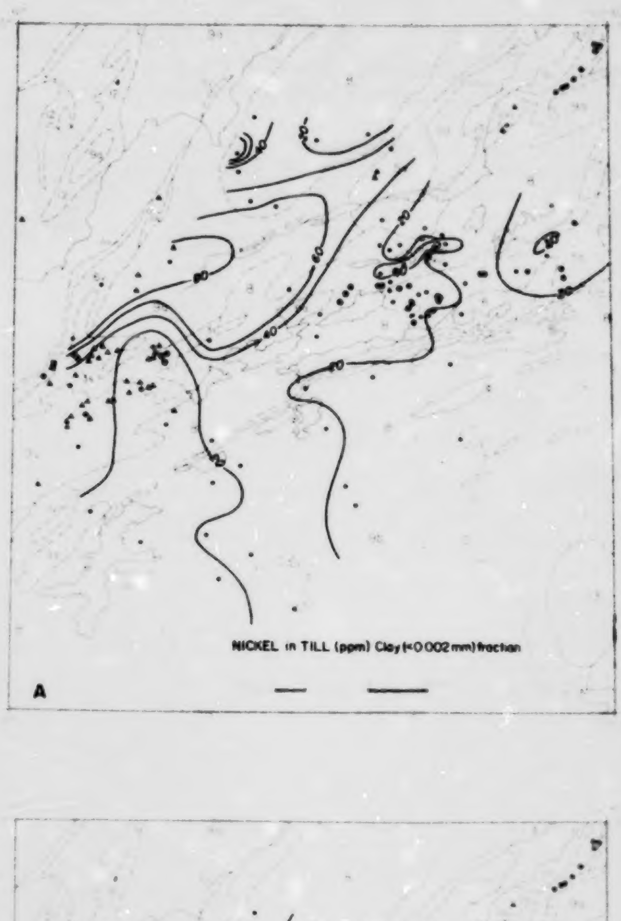
NICKEL in TILL (ppm) Clay (<0.002 mm) fraction
A
80
60
40
20
NICKEL in TILL (ppm) 2-4 mm fraction
B
30
20
10

Figure 7. *Regional variation in the nickel content in the (A) clay-size (<0.002 mm) and (B) pebble-size (2-4 mm) fractions of till. Bedrock geology is explained in Figure 1.*

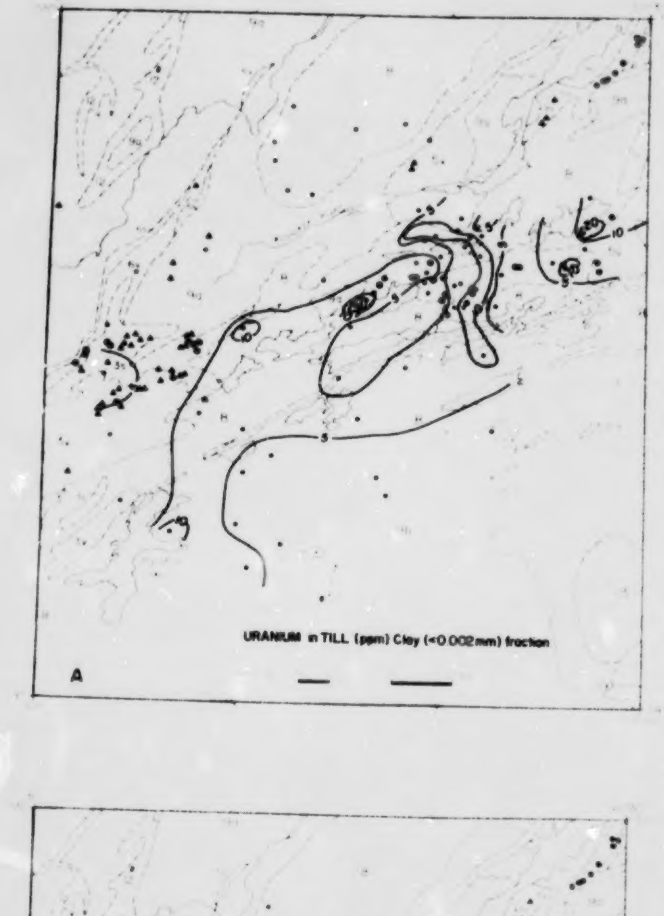
URANIUM in TILL (ppm) Clay (<0.002mm) fraction
A
10
5
URANIUM in TILL (ppm) 2-4mm fraction
B
0.5
1.0
9b

Figure 8. Regional variation in the uranium content in the (A) clay-size (<0.002 mm) and (B) pebble-size (2-4 mm) fractions of till. Bedrock geology is explained in Figure 1.

were found in pits dug in areas of 'background' and 'anomalous' metal levels. Because there is less relative change in metal concentration among samples collected near the base of the B or upper C soil horizons, the least oxidized sediment provides a better basis for geochemical comparison among samples from different sites.

Despite the geochemical variation related to weathering, broad trends in the geochemistry of till appear to reflect differences in regional bedrock geology (Fig. 6 to 8). The general distribution of trace elements in till is similar for the clay and pebble fractions, although contour patterns are slightly more complex for the clay fraction. Contoured patterns follow the regional northeast to east strike of the principal bedrock units, and trace element levels can vary significantly across the study area.

Copper and nickel levels are greatest in the northwest part of the study area, in areas of gneiss of the Nain Province, and are least in the southeastern part in areas of gneiss and granitoid rocks of the Grenville Province. Areas of Bruce River volcanic rock in the west-central part, which are characterized by numerous reported sites of copper mineralization (Ryan, 1982a, b), are not associated with regionally higher levels of copper in till (Fig. 1).

High copper and nickel concentrations at the western edge of the granite complex north of Kaipokok River could be due either to the composition of local bedrock or to northeastward glacial transport of metal-enriched till. Although the correct interpretation is not known, it is noted that elsewhere over the granite, metal concentrations are low. Till to the southwest (up ice) of the granite, however, is characterized by regionally elevated metal levels.

Regional geochemical patterns associated with uranium differ from those of copper and nickel and outline a central zone of enrichment that is more or less coincident with supracrustal rocks of the Central Mineral Belt and, in particular, the Aillik Group. Within the central zone, single samples characterized by anomalously high uranium levels occur. The significance of the anomalous samples is unclear, although they would appear to be related to local bedrock sources. Sites of known uranium mineralization (Fig. 1) are reported by Ryan (1982a, b).

CONCLUSIONS

The principal directions of ice flow within the study area during the last regional phase of glaciation are northeastward in the northern part of the area and eastward to southeastward in the southern part. There is indication of an earlier, nearly northward to north-northeastward phase of flow. Erratics of sedimentary rock derived from supracrustal bedrock suites have been found to the eastern limits of the area, demonstrating glacial transport distances of more than 100 km.

The geochemistry of till is influenced by weathering (soil formation), and trace metal levels are greatest within sediment of the least weathered (C horizon) zone for the clay-size (<0.002 mm) and pebble-size (2-4 mm) fractions. Consequently, analysis of the till collected from the C horizon is considered to provide the best basis for geochemical comparison of samples collected from different sites.

Patterns of regional geochemical variation in till generally outline the major geological units, although elevated metal levels do not necessarily indicate areas of greatest mineral potential, as indicated by the distribution of mineralized showings in bedrock. The trace element levels in till reported here provide a background for the recognition of anomalous samples encountered at a more detailed scale of sampling within the Melody Lake area.

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GEOCHEMICAL ORIENTATION STUDIES AND QUATERNARY MAPPING AROUND THE STRANGE LAKE DEPOSIT, NORTHERN LABRADOR

by

J.W. McConnell, D.G. Vanderveer,
M.J. Batterson and P.H. Davenport
Geochemistry and Environmental Geology Sections

Introduction

An intensive ten-day field study was undertaken over and around the Strange Lake Zr-Nb-Y-Be-rare earth element deposit in Northern Labrador about 130 km west of Nain near the Labrador-Quebec border (Figure 1). The deposit was discovered by the Iron Ore Company of Canada as a result of following up a geochemical anomaly in the regional lake sediment and water survey carried out under the Canada-Newfoundland Uranium Reconnaissance Program (Geological Survey of Canada, 1979).

In the regional geochemical data, the deposit is reflected by a pronounced F anomaly in lake water with associated U in lake water and Pb in the lake sediments. As the deposit itself lies to the west of the regional survey area, the lake sediment and water anomalies are due to a combination of glacial and hydromorphic dispersion.

The objectives of this preliminary study are to characterize the geochemical signature of this type of deposit, and to begin the development of effective follow-up strategies for evaluating other similar regional geochemical anomalies in the province. An additional goal is to provide data on the Quaternary deposits of the area for future geotechnical and environmental assessments.

Description of Area

The area lies within the Nain - George River Plateau, and the terrain is undulating with east-west trending broad valleys and intervening narrow ridges. The maximum elevation is a little over 600 m, with local relief of up to 75 m. The area is covered by a tundra flora, and it lies within the permafrost zone. The local fauna include abundant caribou (which belong to the George River Herd) and wolves.

The area is heavily drift-covered and rock exposure is scarce (1-2%). The mineral deposit occurs in a suite of peralkaline granites which intrude both Paleohelikian adamellite and high grade biotite gneiss of Aphebian age (Hlava and Krishnan, 1980; Taylor, 1975). The peralkaline granites are composed of K-feldspar, quartz, albite and riebeckite with or without aegerine, together with accessory zircon, gittinsite, fluorite, hematite, pyrochlore and allanite (Hlava and Krishnan, 1980). Locally peralkaline pegmatites are present. The location of the eastern boundary of peralkaline granite (Figure 1) is approximate, based on very limited outcrop and diamond drilling results contained in Hlava and Krishnan (1980).

Geochemical Sampling

Samples of lake sediment and water, stream sediment and water and till were collected from parts of NTS sheets 24A/8 and 14D/5 (Figure 1), as detailed below:

1) high density lake sediment and water sampling from 107 sites;

2) stream sediment and water sampling from 140 sites;

3) till and frost boil sampling from about 200 sites, with the sample density decreasing away from the deposit.

The lake waters are being analyzed for Y, F, U and pH. The lake sediments are being analyzed for U, Cu, Pb, Zn, Co, Ni, Cd, Ag, Mo, F, Mn, Fe and LOI (the suite determined on the regional sample set). In addition, they will be analyzed for W, Be, Th, Y, Li and rare earth elements. In a recent survey by the Quebec Department of Energy and Resources in the adjacent area of Quebec, it appears that Be, Th and Y, together with Ce, Eu, La and Sm in lake sediment may be useful guides in locating this type of deposit (Beaumier, 1982). From the samples collected this summer, it should be possible to characterize fully the geochemical signature of the deposit in lake sediments. A similar range of elements is being determined on the stream sediments and waters; in addition, Sn will be included for the stream sediments.

For the till and frost boil samples, a similar wide range of elements (including Sn) will be determined to find the most

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Project funded by the Newfoundland Department of Mines and Energy.

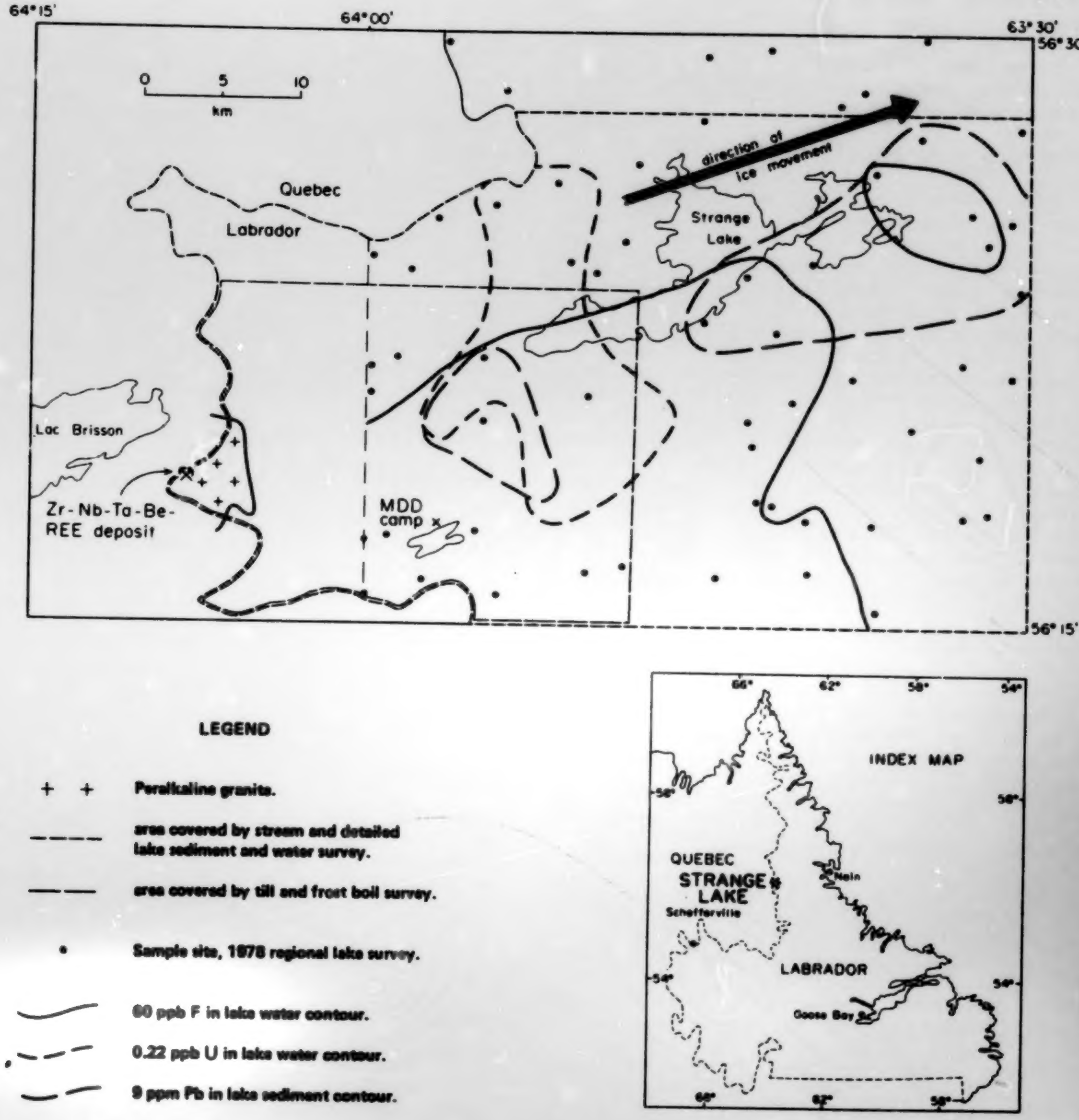
64°15'
64°00'
63°30'
56°30'
56°15'
0 5 10
km
direction of ice movement
Quebec
Labrador
Strange Lake
Lac Brisson
Zr-Nb-Ta-Be-REE deposit
MDD camp x
LEGEND
+ + Peralkaline granite.
area covered by stream and detailed lake sediment and water survey.
area covered by till and frost boil survey.
Sample site, 1978 regional lake survey.
60 ppb F in lake water contour.
0.22 ppb U in lake water contour.
9 ppm Pb in lake sediment contour.
66°
62°
58°
54°
INDEX MAP
QUEBEC
STRANGE LAKE
Schefferville
Nain
LABRADOR
Goose Bay

Figure 1: *Area of till, frost boil, stream sediment and water, and detailed lake sediment and water sampling in the "Strange Lake" area, Labrador. Also shown are the regional geochemical survey sample sites and anomalies in F, Pb and U related to the deposit, and the extent of the host peralkaline granite.*

useful suite of elements with which to map the glacial dispersion train from the deposit. In addition, lithologic and particle size analyses of tills will be conducted. In conjunction with more detailed till sampling being carried out by R.N.W. DiLabio of the Geological Survey of Canada, we should be able to provide a well documented example of the application of till and frost boil sampling at both semi-regional and detailed scales in exploration for this type of deposit.

Preliminary Geochemical Results

Although most analytical work is still in progress some analyses have been completed including F in lake and stream waters and Be in stream sediments. Both elements have distinctive dispersion patterns. The patterns of F in lake and stream waters are very similar with a broad zone of high values occurring over the entire peralkaline complex; values drop gradually in a down-ice direction (east-northeast) away from the peralkaline granite, and drop sharply to the northwest and southeast. The pattern of Be in stream sediments, by contrast, is more linear forming a narrow belt of anomalous values which transects the peralkaline complex and extends down-ice for at least 30 km. The highest values are concentrated in the area of known mineralization.

Quaternary Mapping

Further to the assessment of geochemical follow-up on the Strange Lake deposit, and as part of the continuing effort by the Department (Vanderveer and Sparkes, 1982) to provide Quaternary data to the mineral exploration industry, Quaternary mapping was carried out in conjunction with the geochemical follow-up studies.

Prior to the field season, 1:50,000 scale Quaternary geology maps were compiled from airphotos for map areas 24A/8 and 14D/5. In addition portions of map sheets 14D/1,2,3,6,7,8,9,10,11 and 12 were interpreted, in order to provide geotechnical and environmental data to assess the selection of routes to the coast and to provide background data for any future environmental assessment. Mapping and sampling of the Quaternary geology of 24A/8 and 14D/5, while useful for geotechnical and environmental assessments, were primarily designed to provide a framework for the interpretation of both geochemical data and the results of the airborne gamma-ray survey of N.T.S. map sheets 24A/1 and 24A/8 released by the Geological Survey of Canada (1983).

As part of the Quaternary mapping field program, till and frost boil sampling was carried out on 24A/8 and 14D/5. In total 271 samples were collected from 200 sites and in most cases a collection of pebbles (+ 16 mm to - 32 mm size) was made for lithological studies. In the vicinity of the Strange Lake orebody, samples were collected at 500 m intervals on north-south grid lines spaced at 1000 m. Outside the main claim area on map area 24A/8 samples were collected at 1000 m intervals on north-south grid lines spaced at 2000 m intervals. On map area 14D/5, samples were collected at 2000 m intervals on lines spaced 2000 m apart.

Some profile sampling was carried out which involved a B horizon soil (Fe, oxidize stained, red-brown) sample and a transition B-C horizon soil sample. The latter was usually richer in silt or fine sand due to the percolation of water through the soil (i.e. a hybrid or gradational zone between the B horizon and the parent soil material). This transition zone was usually about 0.5 m thick, whereas the B horizon was only about 0.1 m thick. A parent soil (till) sample was taken wherever exposed.

Preliminary Observations

Glacial drift in the area is extensive and the main elements are shown in Figure 2. The only outcrops are confined to small patches on the topmost parts of the hills or to scattered exposures along the major rivers.

The overburden consists of a compact gray basal till unit that has a mixed silt and sand matrix. Overall, characteristics of the unit are consistent with those of a lodgement till. This unit is overlain by a sandy till deposit which is less compacted than the underlying unit and which exhibits evidence of sorting and washing. Deposition was probably by a melt-out process. The washed matrix of pink sand (medium to coarse grained) is a distinctive feature of this unit that aids in its identification during frost boil sampling.

Glacial transport directions are remarkably consistent across the area, and from the valley to the hilltops no discernible transport differences were observed. The general trend of ice movement was 070°. Some local variations on a particular outcrop may be observed as the glacier ice moved either up and over or around the sides of the bedrock obstruction.

The most conspicuous landform features of the area are the numerous well developed crag and tail hills and drumlinoid features, 1 to 4 km in length, which parallel the direction of glacial transport. The valleys between these features are gener-

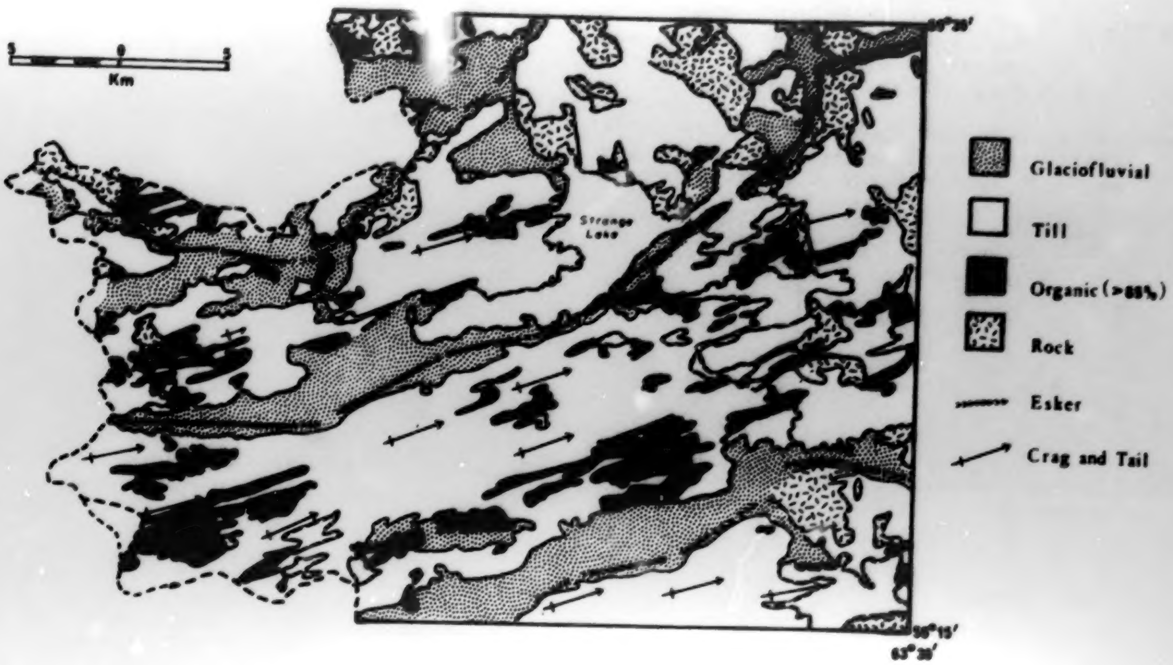

Figure 2: *Surficial landforms, Strange Lake (24A/8, 14D/5).*

ally shallow and slope towards the east. These shallow valleys are frequently the site of boulder pavements due to a combination of postglacial washing (meltwater channels) and present day erosion, particularly during spring breakup. The south-facing side of the crag and tail and drumlinoid hills are often steeper and less well vegetated than the north slopes. This may be the result of periglacial action and present day semipermanent or seasonal ice and snow accumulations.

The major river valleys (e.g. that occupied by (Strange) Esker Lake) are the sites of extensive expanses of ribbed moraine, as well as esker and other glaciofluvial and/or glaciolacustrine deposits. These materials generally have shallower thickness than the till deposits at higher elevations.

Conclusion

Pebble lithology and grain size data for the till and frost boil samples will be evaluated, with the geochemical data, to find the most useful parameters, or suite of elements, with which to map the glacial dispersion train from the deposit. In conjunction with the more detailed till sampling being carried out by R.N.W. DiLabio of the Geological Survey of Canada, we should be able to provide a well documented example of the application of till and frost boil sampling at both semi-regional and detailed scales in exploration for this type of deposit.

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SUMMARY OF FIELD WORK IN THE NORTHERN LONG RANGE MOUNTAINS, WESTERN NEWFOUNDLAND

by

Philippe Erdmer
Newfoundland and Labrador Mapping Sections

Also in Current Research, Part A. Geological Survey of Canada, Paper 84-1A.

Abstract

In preparation for mapping the Precambrian terrane of the northern Long Range Mountains of Newfoundland at 1:100,000 scale, two strips were mapped in 1983, along the western side of White Bay and along the Upper Humber River. The report presents a review of the tectonic nature of the terrane, followed by generalized geological maps and descriptions of the major rock units of the two mapped strips. An Helikian or older quartzofeldspathic basement gneiss complex, at least part of which is metasedimentary, was intruded by a gabbro-anorthosite massif and by megacrystic granitic rocks of probable Neohelikian age. Metamorphic grade is generally in the amphibolite facies, with granulite grade rocks occurring locally; a retrograde greenschist event affected the entire eastern portion of the terrane.

Introduction

The Precambrian terrane of the northern Long Range Mountains is a high grade granite-gneiss complex that is generally assumed to be an inlier of the Grenville Province in the miogeoclinal belt of the Appalachian Orogen. It occupies nearly 8500 km^2 of the Great Northern Peninsula of Newfoundland (Figure 1). Of this area, only about 2000 km^2 have been mapped systematically, at 1:125,000 scale (Bostock, 1983); little is known about the remaining portion which extends over parts of fourteen 1:50,000 scale NTS map areas. Mapping of the remaining area at 1:100,000 scale is to be initiated in the near future. In preparation, a reconnaissance project was carried out in the summer of 1983.

Tectonic Setting of the Precambrian Terrane

One of the principal aims of future systematic mapping will be to compare the rock types and tectonic framework of the region with those of the Grenville Province in adjacent southern Labrador. Little is known about the rocks underlying the Strait of Belle Isle, which separates insular Newfoundland from Labrador. If the Long Range Mountains constitute an inlier, many similarities to the mainland Grenvillian rocks can be expected. However, if strong contrasts are found or if the similarities are weak, the autochthonous nature of the terrane will be in doubt; the 'inlier' may have been displaced from the more interior parts of the Appalachian Orogen during Paleozoic tectonism.

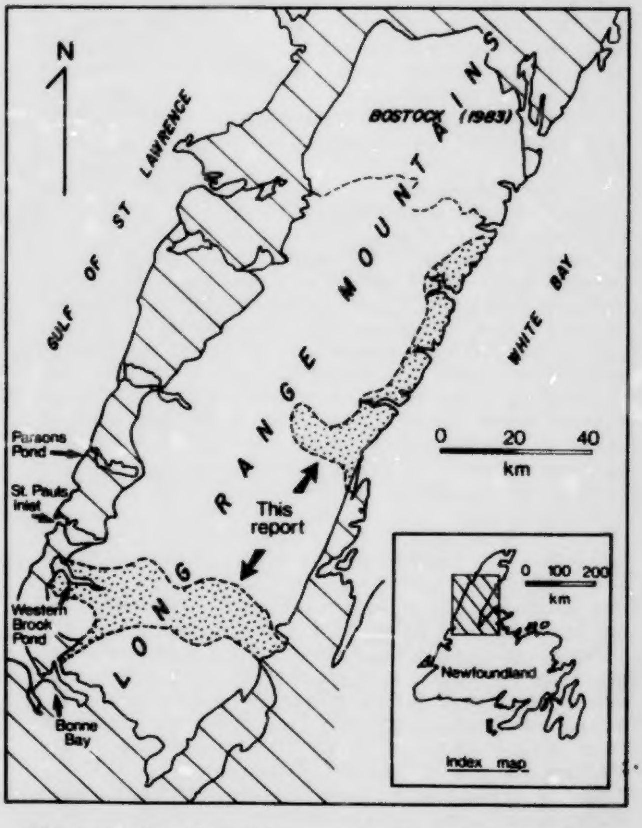


Figure 1: *Location of the Precambrian terrane of the northern Long Range Mountains. Paleozoic rocks are shown by hachures. Bostock's (1983) map area and the two strips mapped for the present study (dot pattern) are outlined.*

Contribution to Canada-Newfoundland co-operative minerals program 1982-84. Project funded by the Geological Survey of Canada.

The hypothesis of an overthrust Long Range Mountains terrane was proposed in several early reports of field work at the periphery of the Precambrian rocks. It is also suggested by more recent geophysical observations.

Schuchert and Dunbar (1934) reported that the Precambrian gneiss was thrust over the Paleozoic rocks on the shore of Western Brook Pond. Johnson (1941a,b) concluded that a major east dipping thrust underlies the entire western boundary of the terrane, carrying it over the Paleozoic platformal assemblage to the west. He showed the apparent dip of this fault to be approximately 60° to the east in two cross-sections, and reported the fault to be "almost flat" in an exposure on St. Pauls Inlet. Oxley (1953) also interpreted the contact as a thrust and reported a dip of 34° to the southeast for the fault near Parsons Pond. Similarly, Nelson (1955) suggested the presence of a high angle thrust fault at the boundary. It appears that none of the outcrops described by these authors has been critically re-examined.

The observation that Paleozoic cover rocks in several localities southwest of the margin of the terrane (in the Bonne Bay - Bonne Bay Big Pond area) contain at least three sets of folds (H. Williams, personal communication, 1983) whereas the Precambrian rocks display no equivalent strain, suggests the presence of a decollement at or near the unconformity surface, and differing structural histories for rocks on either side of the contact. This implies at least a parautochthonous character for some of the cover rocks, and suggests the possibility of basement reworking.

On the basis of a paleomagnetic comparison of rocks in western Newfoundland and mainland eastern Canada, Black (1964) concluded that Newfoundland rotated 30° anticlockwise away from Labrador in the Middle to Late Devonian. Although Deutsch and Rao (1977), together with other workers, considered Black's data inconclusive, new measurements led them to conclude that a rotation of 5 to 10° since the Ordovician is possible. Pullaiah et al. (1979), from a reconnaissance study of the Late Hadrynian Long Range dikes, observed that the remanent magnetization of these rocks contains a steeply inclined component that is misaligned with published late Precambrian directions for both Newfoundland and mainland North America; they attributed this discrepancy to a Devonian overprint. However, other interpretations (i.e. terrane displacement) cannot be ruled out until further testing.

A gravity gradient trending diagonally across the area (Haworth et al., 1980) suggests that deep crustal structure is not reflected in the surface distribution of rock types and that the underlying crust may not be entirely sialic. A well defined positive Bouguer gravity anomaly is centered on the southeast portion of the terrane.

To a large extent, the configuration of east dipping faults beneath the Precambrian rocks can only be determined through deep crustal geophysical measurements similar to those of Cook et al. (1979) in the southern Appalachians. Such a study is being considered as part of a Lithoprobe transect through eastern Canada.

In summary, the physical continuity of the Precambrian rocks of the Long Range Mountains with those of the adjacent Canadian Shield is widely assumed (e.g. Williams and Hatcher, 1983; Keppie, *in press)*, but it has not yet been established. On the basis of the above evidence, the paleogeography of the entire region appears unclear. Further investigation may prove the 'inlier' to be either truly autochthonous or displaced Grenvillian crust.

Previous Work and Present Investigations

Previous work in the portion of the inlier not covered by Bostock's (1983) study is summarized below.

Murray and Howley (1881, 1918) examined the east coast of the Great Northern Peninsula and reported mainly granitic gneiss intruded by northeast trending greenstone dikes. Foley (1937) and Fritts (1953) made four traverses across the peninsula, along which they observed various gneissic units of inferred metasedimentary origin, foliated and massive granitic rocks and crosscutting diabase dikes. The British Newfoundland Corporation Ltd. made a reconnaissance survey of the entire terrane in 1954, which resulted in a map at the scale of 1 inch to 2 miles (Harrison and Johnston, 1954).

On a reconnaissance map at the scale of 1 inch to 4 miles, Baird (1959) indicated the presence of gabbro, anorthositic gabbro and anorthosite, along with various granitoid and mafic gneiss units in the southern portion of the terrane. Clifford and Baird (1962) produced the first comprehensive map of the terrane, at approximately 1:100,000 scale. Partly on the basis of data assembled from previous workers, their map shows granitic and basic intrusions of three types within older gneiss,

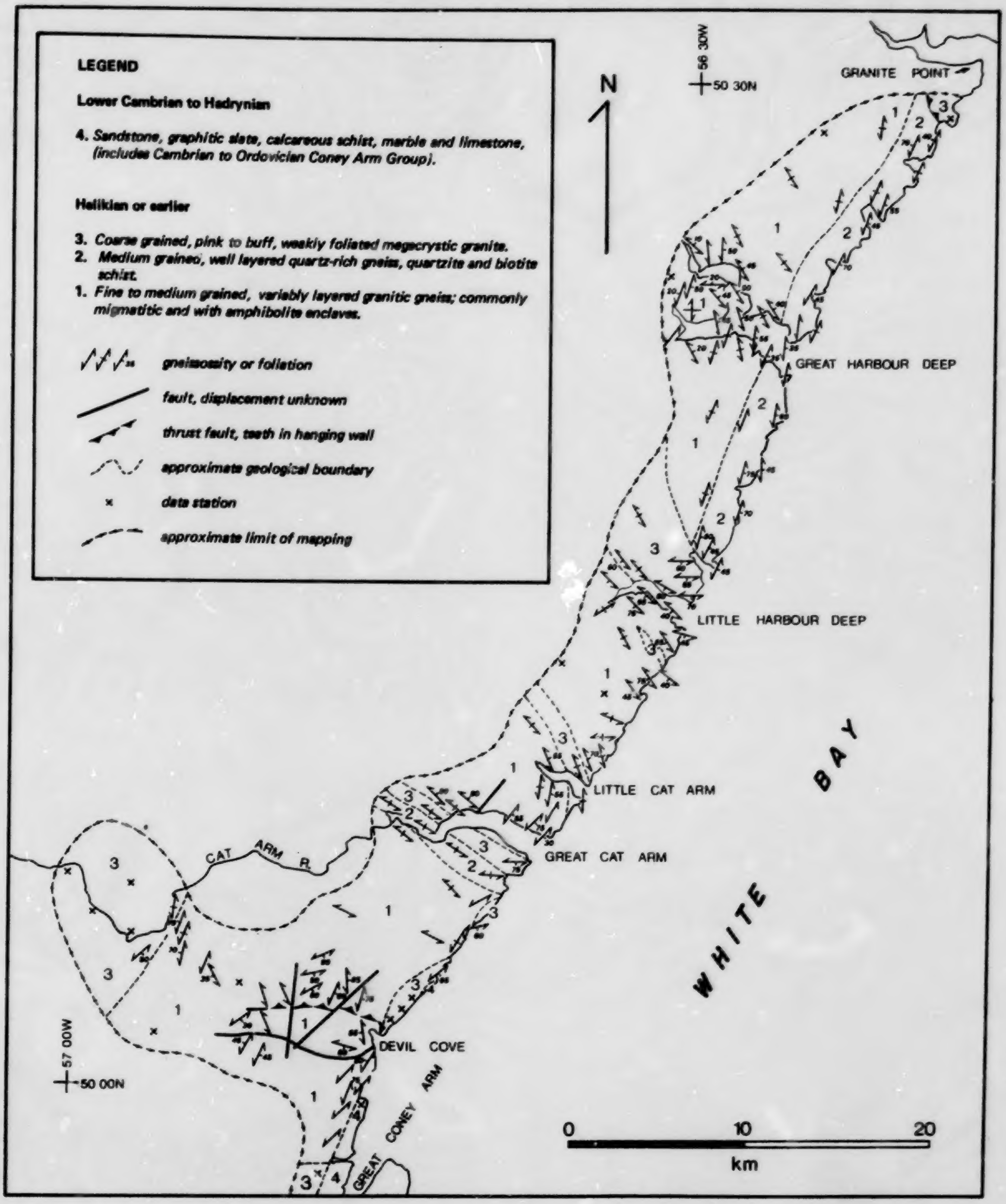

LEGEND
Lower Cambrian to Hadrynian
4. Sandstone, graphitic slate, calcareous schist, marble and limestone, (includes Cambrian to Ordovician Coney Arm Group).
Helikian or earlier
3. Coarse grained, pink to buff, weakly foliated megacrystic granite.
2. Medium grained, well layered quartz-rich gneiss, quartzite and biotite schist.
1. Fine to medium grained, variably layered granitic gneiss; commonly migmatitic and with amphibolite enclaves.
gneissosity or foliation
fault, displacement unknown
thrust fault, teeth in hanging wall
approximate geological boundary
data station
approximate limit of mapping
N
56 30W
50 30N
GRANITE POINT
GREAT HARBOUR DEEP
LITTLE HARBOUR DEEP
LITTLE CAT ARM
GREAT CAT ARM
CAT ARM R.
DEVIL COVE
CONEY ARM
GREAT
WHITE BAY
57 00W
50 00N
0
10
20
km

Figure 2: *General geology of part of the east margin of the Precambrian terrane along White Bay. Data stations shown as 'x' are where no structural observations were made.*

and the extent of the Long Range dike swarm; they also reported the occurrence of various schist and gneiss units, and quartzite and metaconglomerate. The regional metamorphic grade was considered to be middle amphibolite. Neale and Nash (1963) mapped the distribution of biotite- and hornblende-rich gneiss and granite units and metagabbro along part of the southeastern margin of the terrane at the scale of 1 inch to 4 miles.

Pringle et al. (1971) reported a Rb/Sr age determination of 1130±90 Ma and a K/Ar age of 840±20 Ma for megacrystic granite in the Hawkes Bay - Portland Creek area. Cumming (1973a,b) and Bostock and Cumming (1973) briefly examined the Precambrian rocks of Gros Morne National Park, and reported the presence of granulite facies gneissic rocks and the existence of a large, apparently domal structure at the head of Western Brook Pond. Stukas and Reynolds (1974) studied several of the Long Range dikes west of Great Harbour Deep, for which they determined an $^{40}Ar/^{39}Ar$ age of 605±10 Ma; they also concluded that the apparent range of K/Ar ages from 756 to 865 Ma for samples from a single dike (reported by Pringle et al. (1971), within the area mapped by Bostock (1983)) results from excess radiogenic argon and should not be interpreted as the dates of emplacement of the dike swarm.

In the light of these studies, the main objectives of 1983 field work were to examine two strips of the terrane, one along the northeast trending coastal section on White Bay, and the other centered on the Upper Humber River between Western Brook Pond and Taylor Brook. A secondary objective was the examination of the area scheduled to be flooded in 1984 as part of the Cat Arm hydroelectric development, and of the bedrock exposed during the construction of dams and tunnels for this project. The results presented below are a contribution to the planned complete study of the inlier, which will aim to answer many of the questions raised by the present regional geological and geophysical data.

Results of 1983 Field Work

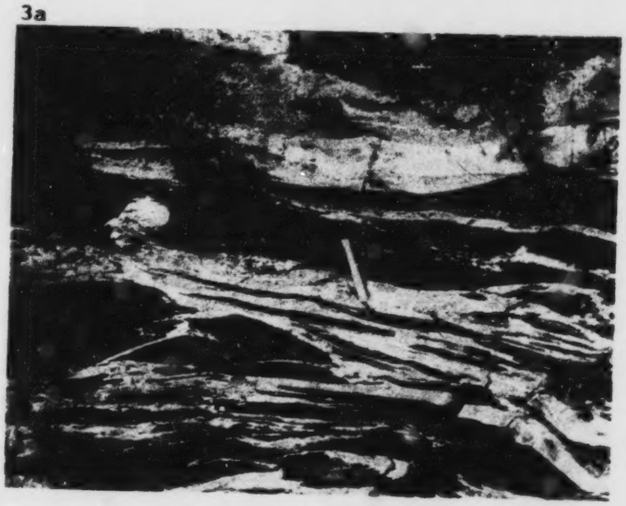
1. Coastal Section

The geology of the Precambrian rocks along White Bay, between Great Coney Arm and Granite Point, is shown in Figure 2. Exposure is excellent along White Bay, and fair to poor inland from the coast.

a. Map units

Unit 1 includes a variety of rock types that are broadly grouped as quartzofeldspathic gneiss. They are pink to gray, heterogeneous, medium to coarse grained, generally well layered but equigranular in places, migmatitic hornblende or biotite granitic gneiss (Figure 3). This gneiss includes abundant layers and lenses of amphibolite, some crosscutting and others conformably interlayered, suggesting more than one protolith. They are interpreted in large part as relict dikes. Similarly, pegmatite and migmatite veins and segregations both follow the gneissosity and truncate it. Thinly laminated layers of quartz-rich gneiss are present in many outcrops within

3a



3b

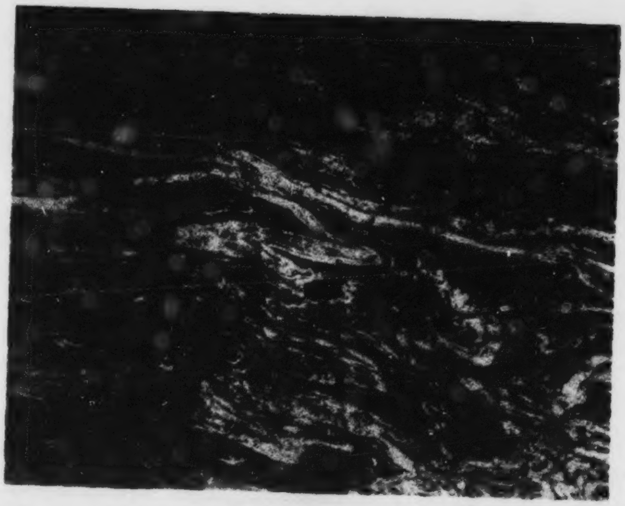


Figure 3: **(a)** *Granitic gneiss and interlayered amphibolite of Unit 1.* **(b)** *Heterogeneous, tightly folded gneiss of the same unit. Both photographs are from outcrops on the shore of White Bay.*

Unit 1; this gneiss is differentiated as Unit 2 on the map where extensive. It is considered to be of metasedimentary origin. Other layers include pink, megacrystic orthogneiss of granitic to monzonitic composition that is correlated with the rocks of Unit 3. Unit 1 thus contains rocks of differing protoliths, and is likely to have had a prolonged strain history. Pending further subdivision, Unit 1 is correlated with the bulk of the old gneiss complex to the northwest (Bostock, 1983), which is of Helikian or older age.

Unit 2 is exposed in two elongate slices several kilometres long which are interlayered with Unit 1. It is an assemblage of dominantly medium grained, gray to white, finely banded quartz-rich gneiss (in which quartz forms up to 90% of the rock, and feldspars and biotite the remainder), medium grained quartzite, and minor medium to fine grained biotite schist (Figure 4). Other minor rock types such as chlorite schist, fine grained amphibolite and transitional layers are present in a few outcrops. A few gossan areas of 10 to 40 m^2 each were noted in layers of Unit 2 on the coast. Mineralization appears to be mostly disseminated pyrite, and minor chalcopyrite or hematite and magnetite. A metasedimentary origin is inferred for most of the rocks of Unit 2. The unit is correlated with minor rock types (pelitic schist, muscovite chlorite schist, amphibolite and quartz-rich gneiss) differentiated by Bostock (1983) within the basement gneiss to the northwest, for which a Helikian or older age has been established.

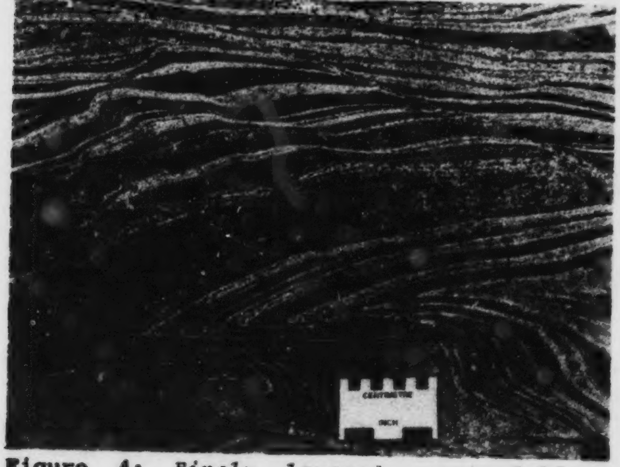


Figure 4: *Finely layered quartzofeldspathic and quartz-rich gneiss of Unit 2, north of Little Harbour Deep.*

Unit 3 comprises a variety of dominantly coarse grained, megacrystic, massive to weakly foliated granitic rocks exposed in several places along the coast and inland (Figure 5). Their relation to Units 1 and 2 appears to be mainly intrusive, although the contact was moderately to strongly modified by later strain and is generally poorly exposed. Where it is exposed, the rocks of Unit 3 crosscut the main gneissic fabric, and have been involved in a subsequent, less intense deformation. To the west of Great Coney Arm, the rock is generally massive, coarse grained and commonly subporphyritic, buff granite with a characteristic dark green,

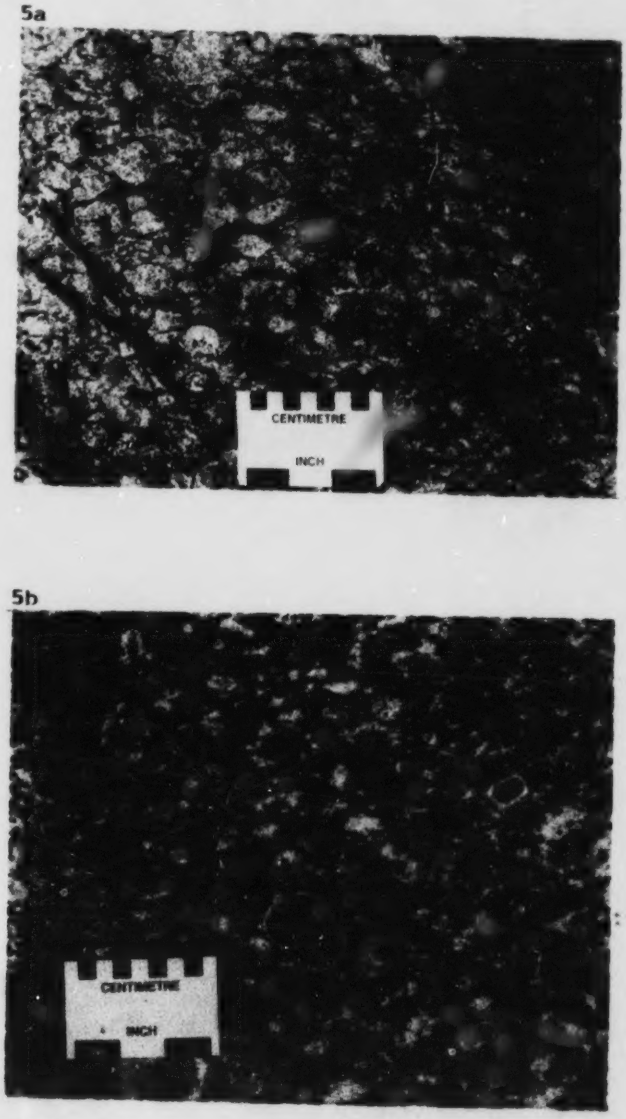


Figure 5: (a) *Foliated megacrystic granite of Unit 3 near Little Harbour Deep.* (b) *Massive granite of Unit 3 north of Devil Cove.*

relatively fine grained groundmass. The body exposed along the upper Cat Arm River is medium to coarse grained, almost equigranular, pink, leucocratic granite that is well foliated near its contact with the gneiss of Unit 1. Between Devil Cove and Great Harbour Deep, the rocks included in Unit 3 are moderately to strongly foliated, pink, megacrystic (K-feldspar) granite to alkali feldspar granite the protoliths of which may differ in age. The granite near Granite Point is a massive, equigranular, biotite-bearing, leucocratic rock that overlies the gneiss to the west along a shallow dipping mylonite zone (see discussion of structure). The diversity of rock types within Unit 3 suggests that distinct intrusive suites with slightly different compositions are represented. The rocks of Unit 3 are correlated with other post-tectonic but pre-Grenvillian granite bodies exposed in the region to the north (Bostock, 1983; Pringle et al., 1971).

Units 1 to 3 are crosscut by numerous diabase and metadiabase dikes of the Late Hadrynian Long Range swarm, which measure a few centimetres to more than 50 m across strike. These dikes invariably strike east-northeast; dips vary from vertical to steep to the southeast or northwest.

Unit 4 includes east dipping clastic and carbonate strata that lie unconformably on Units 1 to 3. The erosional unconformity is exposed in two localities along the coast, 2 km to the south and 3 km to the north of Devil Cove, and in many places along the access road to the Cat Arm Development site. The basal rock type is a thin layer (1 to 20 m) of blue-quartz pebble conglomerate and sandstone of the Beaver Brook Formation (Smyth and Schillereff, 1982), which has been correlated with the Eocambrian Bradore Formation (Schuchert and Dunbar, 1934) exposed around the northern margin of the Precambrian terrane. The Beaver Brook Formation, and the overlying marble, graphitic phyllite and schist, limestone, quartzite and dolomite strata are included in the Cambrian to Middle Ordovician Coney Arm Group, as redefined by Smyth and Schillereff (1982), which is interpreted as an autochthonous Lower Paleozoic platformal assemblage.

b. Structure

The main fabric of Units 1 to 3 is a well developed gneissosity or foliation that is commonly affected in outcrop by irregular, asymmetric tight folds ranging from a few centimetres to several metres in amplitude. Steep dips of the planar fabric are common; a few large (up to 100 m amplitude) overturned to recumbent isoclinal folds are exposed in Unit 1 on the coast. Dip variations and reversals over short distances along strike are commonly observed.

Shallow north to northeast dipping mylonite zones up to 20 m thick, exposed west of Devil Cove and south of Granite Point, are the locus of ductile thrust faulting, as suggested by minor structures in at least one locality (D. Besaw, personal communication, 1983). On the basis of the little data available, thrusting appears to have been south-southwesterly directed. Because the granite of Unit 3 south of Granite Point is thrust over Unit 2 (this relationship confirms Bostock's (1983) observation of a south dipping fault to the north of Granite Point), the faulting appears to be of Grenvillian age.

Two thrust faults reported by Foley (1937) on the north shore of Great Harbour Deep are small, brittle, east dipping structures of which the sense of displacement is unclear, and that are probably related to Paleozoic faulting farther east.

c. Metamorphism

All rocks in Units 1 to 3 are pervasively recrystallized. A saccharoidal, friable texture is characteristic of many of the quartzofeldspathic rocks. Migmatite segregations are developed in many outcrops of Units 1 and 2. Metamorphic hornblende and biotite are present almost everywhere, but no mineral assemblages diagnostic of a well constrained pressure-temperature field were found. Epidote, chlorite and sericite are present in most outcrops along the coast as retrograde minerals in the gneissic and granitic rocks. The Long Range dikes are locally heavily chloritized; this alteration appears to decrease progressively inland to the west.

On the basis of this evidence, metamorphic grade in the crystalline rocks is in the amphibolite facies, with extensive overprinting in the greenschist facies which may be weaker to the west.

2. Southern Transect

The geology of the area between Western Brook Pond and Taylor Brook is shown in Figure 6. Exposure in the region is generally fair to poor to the east of Gros Morne National Park, and good within the park.

a. Map units

Unit 1 includes heterogeneous, leucocratic, pink to gray, medium to coarse grained biotite or hornblende granitic gneiss (Figure 7). It is commonly well

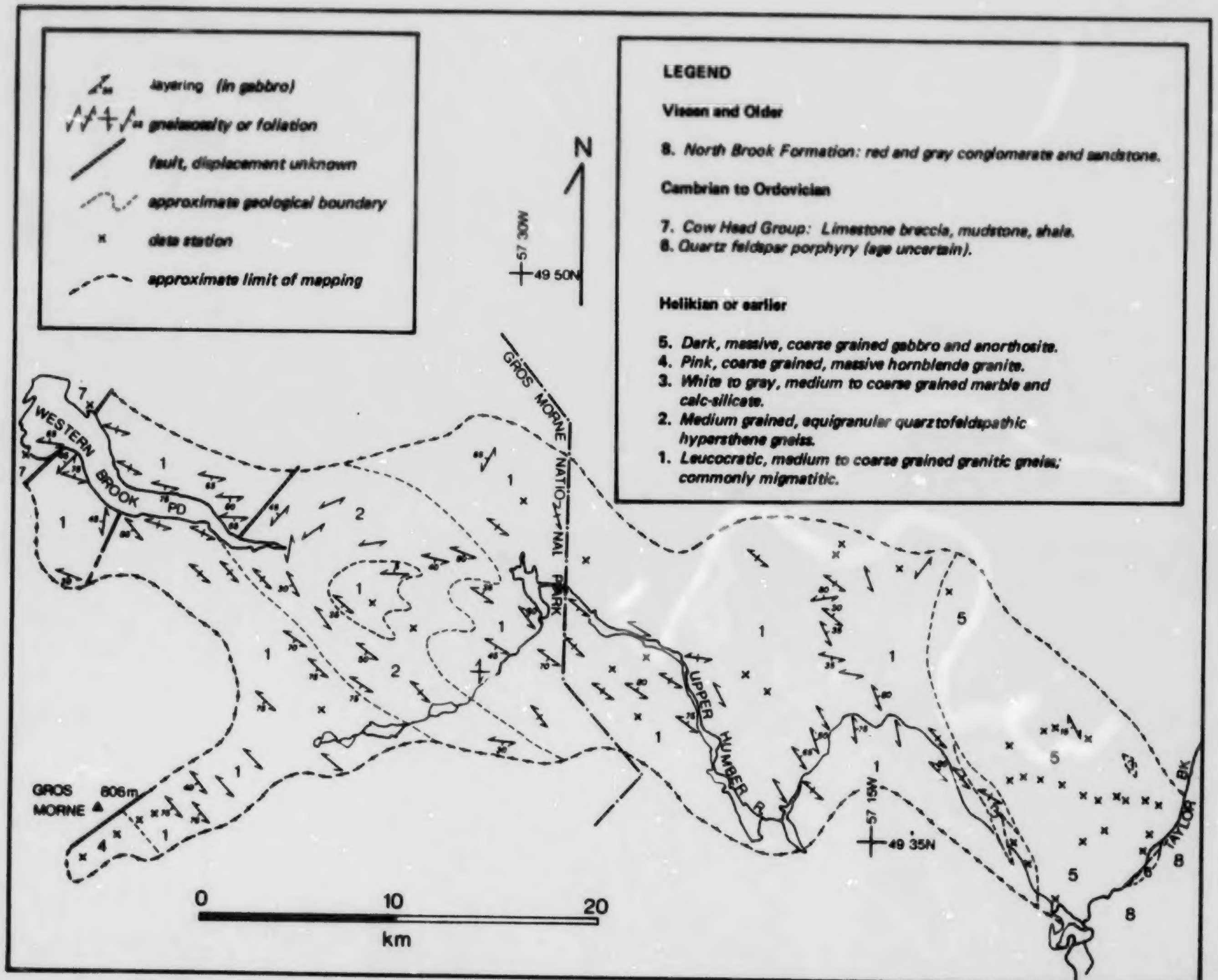

layering (in gabbro)
gneissosity or foliation
fault, displacement unknown
approximate geological boundary
data station
approximate limit of mapping
N
57 30W
49 50N
57 15W
49 35N
LEGEND
Visean and Older
8. North Brook Formation: red and gray conglomerate and sandstone.
Cambrian to Ordovician
7. Cow Head Group: Limestone breccia, mudstone, shale.
6. Quartz feldspar porphyry (age uncertain).
Helikian or earlier
5. Dark, massive, coarse grained gabbro and anorthosite.
4. Pink, coarse grained, massive hornblende granite.
3. White to gray, medium to coarse grained marble and calc-silicate.
2. Medium grained, equigranular quartzofeldspathic hypersthene gneiss.
1. Leucocratic, medium to coarse grained granitic gneiss; commonly migmatitic.
WESTERN BROOK PD
GROS MORNE NATIONAL PARK
UPPER HUMBER R
TAYLOR BK
GROS MORNE
606m
0
10
20
km

Figure 6. General geology of the Upper Humber River region between Western Brook Pond and Taylor Brook. Data stations shown as "x" are where no structural observations were made.

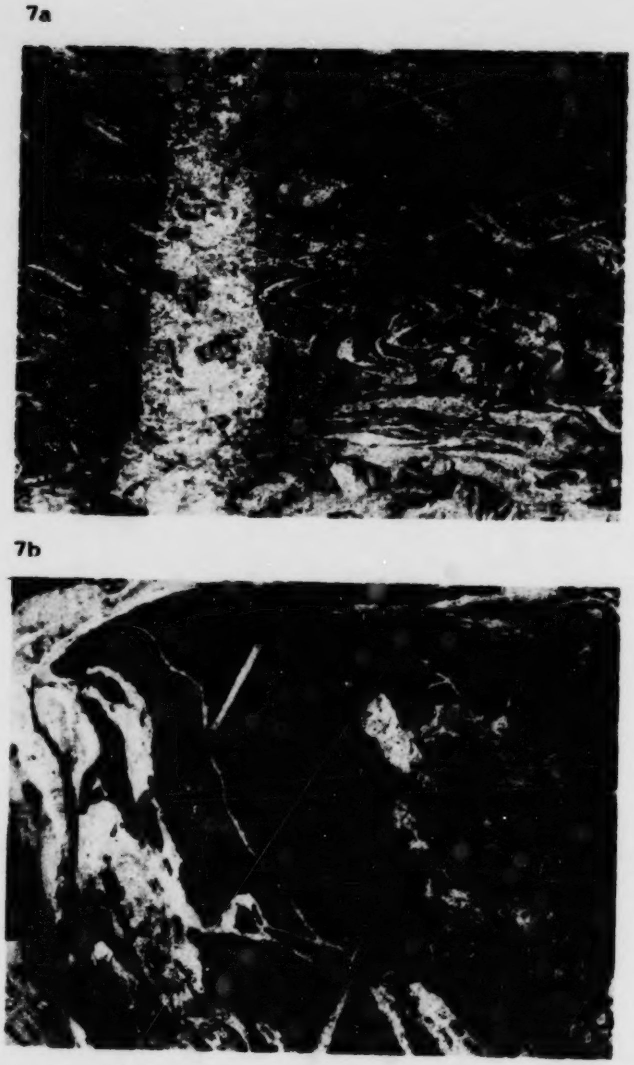


Figure 7: (a) *Well layered, heterogeneous granitic gneiss of Unit 1, near the Upper Humber River.* **(b)** *Amphibolite boudin in the same unit.*

layered and migmatitic, and includes layers and boudins of amphibolite. Although lack of exposure prevents a firm interpretation, the relations between gneiss and amphibolite are probably similar to those observed along White Bay (i.e. both conformable and crosscutting contacts can be seen). Large (up to 6 m across) boulders of distinctive, finely laminated, fine grained sillimanite- and muscovite- rich quartzofeldspathic gneiss occur in the bed of the Upper Humber River near 57°10'W. These boulders appear to be of proximal derivation, and are considered to represent fragments of pelitic layers within Unit 1. Unit 1 is correlated with the old gneiss exposed along White Bay and in the region mapped by Bostock (1983). The unit is interpreted to be of Helikian or older age and to include rocks of diverse protoliths and various ages.

Unit 2 has most of the characteristics and the overall composition of Unit 1, but is distinguished from it by the presence of medium to coarse hypersthene grains and a waxy, dark olive green color of the feldspars in many outcrops. Its contacts with Unit 1 are mostly gradational, except to the north of Western Brook Pond where a prominent, steep, northeast trending fault separates the hypersthene gneiss from the rocks of Unit 1. As a difference of metamorphic grade appears to be the only difference between Units 1 and 2, their protoliths may have been similar. The granulite facies rocks of Unit 2 do not correlate with rocks elsewhere in the Long Range Mountains, but they may be lithologically similar to leucocratic hypersthene gneiss in adjacent Labrador, described by Bostock (1983). The unit is assumed to be Helikian or older.

Unit 3 comprises marble and calc-silicate rocks exposed in two slices within and at the margins of the gabbro-anorthosite body of Unit 5. The sliver of Unit 3 near the Upper Humber River is mostly white to pale gray, coarsely crystalline, in places graphitic marble with some gray, impure, quartz-rich layers. In at least two outcrops near the contact with the gabbro, the marble grades into a brown and green (diopside-bearing?) fine grained rock a few metres thick. The small sliver of Unit 3 within Unit 5 is a mottled gray and brown, fine grained, tremolite-rich(?) calc-silicate(?) rock exposed on an isolated knoll within the gabbro massif. It is included in Unit 3 on the basis of broad lithological similarity, but its relation to the gabbro and to the marble to the west is unclear. It may be similar to bands of tremolite-chlorite-carbonate rock observed by Bostock (1983) in metagabbro to the north. It may be an intensely altered ultramafic phase, or an inclusion within the anorthositic rocks. The marble to the west appears to be interlayered in the gneiss of Unit 1, and to have been intruded by the gabbro along the Unit 1. Unit 3 is considered to be of Helikian age.

Unit 4 is coarse grained, in places megacrystic, massive to well foliated hornblende granite exposed south of Gros Morne. Its contact with the gneiss to the east is gradational, and is assumed to be originally intrusive. Unit 4 is correlated with rocks of the post-tectonic granitoid suite of Bostock (1983), and with parts of

Unit 3 in the coastal region. It is inferred to be of pre-Grenvillian age.

Unit 5 comprises a range of gabbroic to anorthositic rocks that occur in a large (at least 15 km across) intrusive complex between the Upper Humber River and Taylor Brook. Rock types include coarse grained (up to 5 cm) equigranular, ophitic gabbro and metagabbro, fine to coarse grained dark anorthosite and gabbroic anorthosite, medium grained hornblende diorite, and medium grained buff monzonitic rocks. The rocks are generally massive; primary layering is outlined by mafic minerals in the gabbroic rocks. Dikes of gabbroic material in the surrounding rocks, and inclusions of granitic gneiss within Unit 5 are exposed in several outcrops. Rocks of Unit 5 may correlate broadly with rocks of the anorthosite suite recognized in Labrador by Bostock (1983), but they do not appear to have equivalents within the Long Range Mountains. Unit 5 is interpreted to be of Helikian or older age.

Units 1 to 5 are crosscut by numerous diabase dikes of the Long Range swarm, which vary from 1 to 40 m in width, and appear to be generally better preserved here than along White Bay.

Unit 6 is fresh, dark green or pink, fine grained quartz-feldspar porphyry that occurs in several small, low outcrops east of Taylor Brook, and is seen as a diking phase in Unit 5 to the west of Taylor Brook. The rocks are slightly recrystallized and display little strain. They are inferred to be of Hadrynian or younger age, and to have intruded the Precambrian rocks along the southeast margin of the inlier. They may correlate with parts of the Lower Paleozoic Sops Arm Group mapped on strike to the north by Smyth and Schillereff (1982).

Unit 7 is the allochthonous(?) Cow Head Group of Cambrian to Ordovician age (Schuchert and Dunbar, 1934; Oxley, 1953) which comprises interbedded limestone breccia, lime mudstone, calcarenite and shale on the north and south shores of Western Brook Pond. The contact with the gneiss to the east is not exposed; a brief examination of the Precambrian rocks in several localities along the approximate contact reveals extreme brecciation, iron staining and chloritization of the gneiss, which suggest that the boundary is a fault.

Unit 8 is the North Brook Formation (Hyde, 1982) of Carboniferous (Visean) age, which includes red to gray, pebble to boulder conglomerate and interbedded red to gray sandstone and siltstone, and gray and pink limestone. The unit forms the margin of the Carboniferous Deer Lake Basin and lies unconformably on the Precambrian and Lower Paleozoic rocks to the west.

b. Structure

As in most of the rocks of the coastal region, the gneissic rocks of the Western Brook Pond - Taylor Brook area have a well developed main planar fabric that is commonly folded in outcrop by irregular, asymmetric folds resulting from highly ductile strain. Banding in marble is inferred to be transposed original bedding.

The large fold structure outlined by Unit 2 is well exposed at its western extremity and poorly defined in the east. It appears to be a slightly elongate dome; however, discordant dips and the apparent occurrence of lower grade rocks of Unit 1 near its center suggest a more complex structure, such as a nappe of granulite facies rocks infolded with lower grade gneiss into a northwest plunging antiform with its own planar fabric at the center. A detailed structural analysis is needed to test this hypothesis.

The faults exposed north and south of Western Brook Pond are large (longer than 10 km, from aerial photographs) and steep structures that are inferred to have been the locus of at least some dip-slip displacement, as the fault on the north side juxtaposes rocks of clearly different metamorphic grade.

The western contact of the Precambrian rocks was examined only briefly; within the brecciated zone (see above), slickensides in the gneiss appear to be variably oriented. Insufficient data are available to speculate on the nature of the fault that crosses Western Brook Pond.

c. Metamorphism

All rocks in Units 1 to 5 are recrystallized, but they do not appear to have the friable, sucrosic texture noted along White Bay. Migmatite bands and lenses are developed extensively in Units 1 and 2. The sillimanite-bearing rocks of Unit 1 (and diopside-bearing? rocks of Unit 3) suggest that Units 1, 3, 4 and 5 underwent metamorphism in the amphibolite facies; rocks of Unit 2 were metamorphosed in the granulite facies before being emplaced next to the amphibolite facies rocks. Only weak retrogression to greenschist facies conditions is apparent in the region, in contrast to the rocks along White Bay. As noted above, the Long Range dikes are increasingly well preserved toward the west. On Western Brook Pond, several spectacular dikes of this swarm are flinty diabase with no sign of alteration (Bostock and Cumming, 1973).

Acknowledgements

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P. Erdmer

GEOLOGICAL MAPPING OF THE PORT SAUNDERS (12I/11), ST. JOHN ISLAND (12I/14) AND PARTS OF THE TORRENT RIVER (12I/10) AND BELLBURNS (12I/6) MAP SHEETS, NORTHWESTERN NEWFOUNDLAND

by

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Abstract

Gently dipping Lower to Middle Ordovician platformal rocks resting unconformably upon Grenvillian basement rocks underlie the map area. The predominantly granitic Grenville rocks formed an early Paleozoic land surface that had marked local relief. The lower Paleozoic successions include 1400 m of generally conformable siliciclastic and carbonate rocks belonging to the Labrador (Lower Cambrian), Port au Port (Middle to Upper Cambrian), St. George (Lower Ordovician) and Table Head (Middle Ordovician) Groups. Two disconformities lie within the St. George Group.

The platform was affected by faulting in the Early Ordovician. Open spaces along northeast trending faults and joints that cut limestones of the Catoche Formation are filled by lithified, dolomitic, chert-quartz sandstone and dolomitic mudstone which resemble lithologies of the youngest rock unit in the St. George Group, the Aguathuna Formation.

A major system of curvilinear northeast trending faults crosses the map area. Vertical throws of large magnitude (100-1500 m) occurred on many of the faults but fold structures and trends, locally inverted bedding, and stratigraphic relationships suggest that the fault system was also affected by strike-slip movements.

The area hosts several small galena-sphalerite showings, including some in petroliferous dolomites that replaced limestones of the Table Head Group.

Introduction

Mapping of lower Paleozoic platformal rocks at 1:50,000 scale was completed in the Port Saunders, St. John Island and Torrent River map areas, and was begun in the northern half of the Bellburns map area during 1983. The gently inclined platformal rocks underlie a generally undulose wooded terrain that is of low elevation (0 to 100 m) in the southwestern and western parts of the map area, but rise to 380 m in the highlands of St. John, where the hills are [illegible]

The Northern Peninsula highway (Route 73, also called the Viking Highway) provides access to the area from Deer Lake. Paved roads link the main communities of Hawkes Bay, Port Saunders and Port au Choix. Access to the rest of the map area is facilitated by a network of forest access roads of variable quality. Large lakes such as Western Brook Pond (locally referred to as "Wes Lake"), Eastern Blue Pond (locally known as "Bluey") and River of Ponds Lake provide access to more remote areas by [illegible]

Contribution to Canada-Newfoundland co-operative minerals program 1982-84. Project financed by the Newfoundland Department of Mines and Energy.

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ation map by L.M. Cumming *in* Bostock et al. (1983). Smyth (1982) also compiled the geology of the area at 1:250,000 scale.

Geologic Setting

The map area contains almost all of the stratigraphy found in the Cambro-Ordovician platformal sequences in western Newfoundland. The generally gently dipping rocks range in age from Early Cambrian to Middle Ordovician and comprise rocks of the Labrador Group (Early Cambrian), Port au Port Group (Middle to Late Cambrian), St. George Group (Early to possibly early Middle Ordovician) and Table Head Group (Middle Ordovician). A mixed nonmarine to marine siliciclastic carbonate sequence in the Labrador Group is succeeded in the map area by an exclusively carbonate succession in the remaining groups.

The basal platformal strata rest with marked unconformity upon Precambrian basement rocks of Grenvillian age. The unconformity is mostly exposed on the western side of the Torrent River map area, where it has topographic relief of approximately 30 m beneath gently dipping outliers of the Labrador Group, south of Pikes Feeder Pond. One topographic high is bounded by two sets of northwest trending lineaments that are truncated by the unconformity.

Precambrian basement rocks are rare west of the Lady Worcester Brook Fault (LWBF). They do, however, occur unconformably overlain by Labrador Group in a fault-bounded wedge near LWB Fault north of Pikes Feeder Pond, as well as slightly east of the Ten Mile Lake Fault (TMLF) near North Summit of the Highlands of St. John.

The basement rocks that directly underlie the Labrador Group [illegible] of red to pink, [illegible] granite which [illegible]

The subdivisions of the [illegible] zoic sedimentary rocks of the Northern Peninsula are similar to those used by Knight (1978, 1980, 1983).

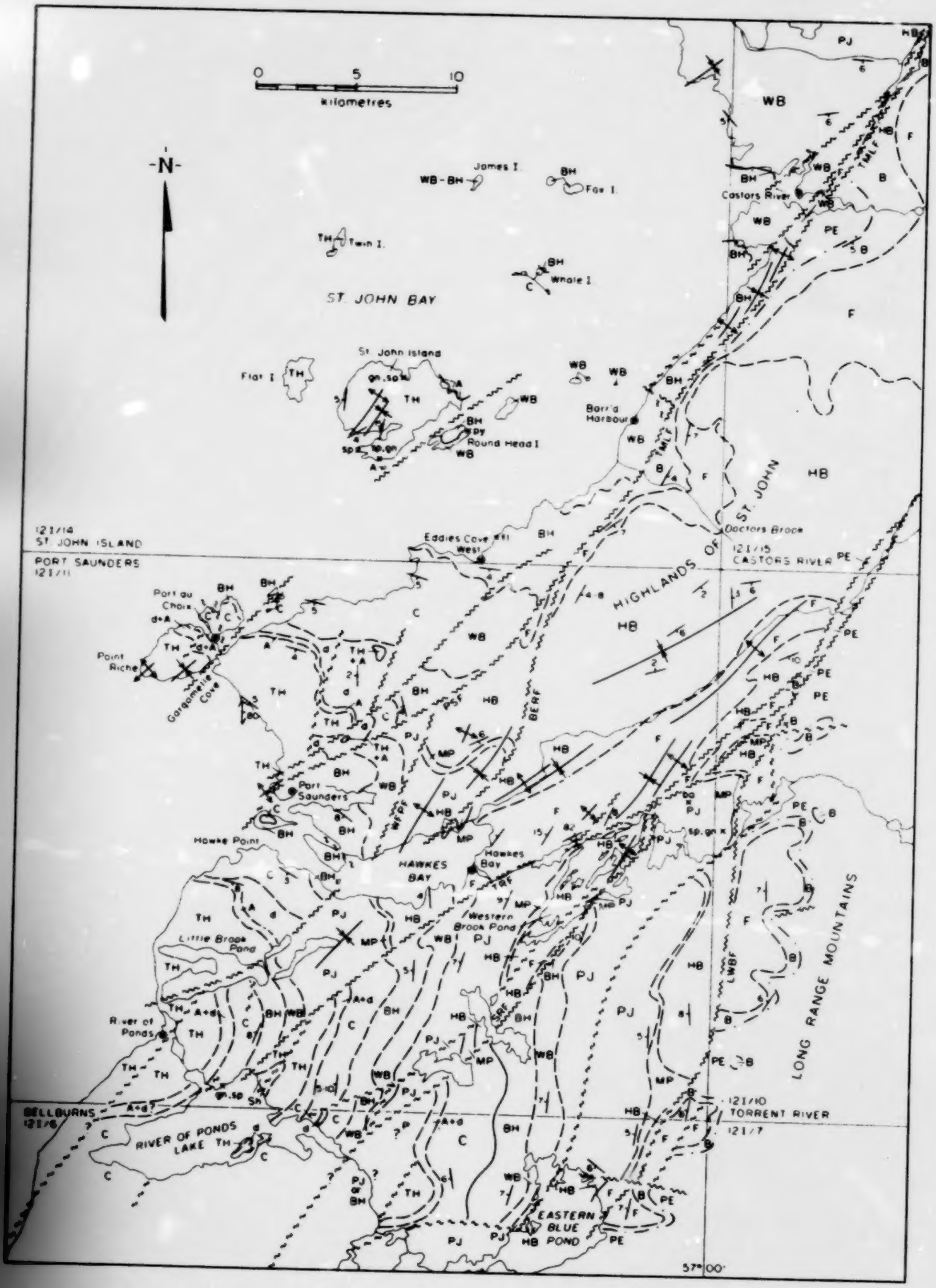
Labrador Group

The Labrador Group, which is approximately 400 m thick, consists of, in ascending order, the Bradore, Forteau and Hawke Bay Formations, which are dominantly siliciclastic but contain minor carbonate rocks.

The basal Bradore Formation (Unit B, Figure 1) consists of red arkosic and gray to pink glauconitic sandstones, grits and minor conglomerate. The map area appears to contain two contrasting successions. In the west along Frenchman's Brook, Doctors Brook and the foot of the western scarp of the Highlands of St. John, the succession is typified by red, cross-stratified, arkosic sandstone with only minor gray sandstone. Pebble beds and grit are common towards the base of the formation; well sorted, *Skolithus* - bearing red and white sandstone is common at the top of the formation. Green-gray, glauconitic, very fine sandstone (some of which was mistaken for a massive diabase sill *in* Knight, 1983) is only a few metres thick and is apparently near the base of the formation. To the east of Lady Worcester Brook Fault, the Bradore Formation consists of a few metres of crossbedded, pebbly brown sandstone and conglomerate, overlain by approximately 50 m of gray and pink, glauconitic, cross-laminated and laminated, very fine sandstone and coarse siltstone, locally intercalated with gray shale. The top of the formation consists of approximately 30 m of red crossbedded sandstone and minor gray sandstone.

The overlying Forteau Formation (Unit F, Figure 1) consists of a lower shale-dominated section overlain by grainy limestone and sandstone. In the lower section, gray and black shales which are manganiferous, fossiliferous and contain calcareous concretions, are intercalated with thin [illegible]

[illegible] sists mostly of white, flinty, quartzose sandstone that displays large scale trough and planar-tabular cross-stratification. Interbedded at scattered intervals in the white sandstone are red, gray and green sandstones and shales. These lithologies


0 5 10
kilometres
-N-
ST. JOHN BAY
James I.
Fox I.
Twin I.
Whale I.
St. John Island
Flat I.
Round Head I.
Barr'd Harbour
Castors River
Eddies Cove West
Doctors Brook
HIGHLANDS OF ST. JOHN
121/14
ST. JOHN ISLAND
PORT SAUNDERS
121/11
121/15
CASTORS RIVER
Port au Choix
Point Riche
Gargamelle Cove
Port Saunders
Hawke Point
HAWKES BAY
Hawkes Bay
Western Brook Pond
Little Brook Pond
River of Ponds
RIVER OF PONDS LAKE
BELLBURNS
121/6
121/10
TORRENT RIVER
121/7
EASTERN BLUE POND
LONG RANGE MOUNTAINS
57°00'
TMLF
BERF
WFDF
TRF
LWBF
WB
BH
TH
HB
PJ
PE
MP
C
F
B
A
d
d+A
A+d
gn.sp
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py

Figure 1: *Sketch map of the geology of the St. John Island, Port Saunders and parts of the Castor River, Bellburns and Torrent River map areas.*

LEGEND

MIDDLE ORDOVICIAN

TH **Table Head Group** - *Limestone, minor dolomitic limestone, dolostone and shale.*

LOWER ORDOVICIAN

St. George Group (WB, BH, C, A)

A Aguathuna Formation - *Dolostone, dolomitic shale.*

C Catoche Formation - *Limestone, top extensively replaced by diagenetic dolostone (d).*

BH Boat Harbour Formation - *Limestone, dolomitic limestone, dolostone, diagenetic dolostones.*

WB Watts Bight Formation - *Diagenetic dolostones, minor limestone.*

MIDDLE TO UPPER CAMBRIAN

Port au Port Group (MP, PJ)

PJ Petit Jardin Formation - *Dolostone, minor shale and limestone.*

MP March Point Formation - *Dolostone, minor shale, sandstone.*

LOWER CAMBRIAN

Labrador Group (B, F, HB)

HB Hawke Bay Formation - *White sandstone, minor shale.*

F Forteau Formation - *Limestone, shale, sandstone.*

B Bradore Formation - *Red and gray sandstone, minor conglomerate.*

PRECAMBRIAN

PE Grenville Basement - *Granite, gneiss.*

SYMBOLS

Unconformity
Geologic contact
Fault (approximate, assumed)
Bedding
Cleavage
Folds
Mineral showing

gn	galena
sp	sphalerite
ba	barite
fl	fluorite
py	pyrite

TMLF	Ten Mile Lake Fault
PSF	Port Saunders Fault
WFPF	Whale Factory Pond Fault
BERF	Big East River Fault
TRF	Torrent River Fault
SRF	Starvation Ridge Fault
LWBF	Lady Worcester Brook Fault

are phosphatic and glauconitic, and exhibit trace fossils, ripple marks and mudcracks.

The Forteau Formation within the map area contains inarticulate brachiopods and the problematic mollusc *Salterella*, as well as trilobites including *Wanneria logani* Walcott, *Olenellus (= Paedumis) transitans* Walcott, *O. lapworthi* Peach and Horne, *O. brevoculus* Resser and Howell, *Bonnia senecta* (Billings) and *Kootenia* sp. nov.. *Olenellus fremonti* occurs in shales in the lower part of the Hawke Bay Formation.

Port au Port Group

The Port au Port Group, which is probably >400 m thick in the map area, rests conformably upon the Hawke Bay Formation. It comprises two units, the March Point and Petit Jardin Formations (MP and PJ, Figure 1), both composed of recessively weathering dolostones and lesser shales. The March Point Formation is approximately 25 m thick on the south shore of Hawkes Bay but is probably approximately 50 m thick in the area east of Western Brook Pond. It consists of rusty to brown weathering, dark gray to gray, argillaceous dolostone, gray and black shale and minor glauconitic sandstone. Interbedded shale, siltstone and rusty weathering, bioturbated, very fine sandstone occur in the basal 3 m of the formation. Phosphatic intraclasts and quartz pebbles occur in the sandstone, which is mostly planar laminated and flaser bedded.

Above the basal member, the formation is dominated by some 15 m of argillaceous dolostone that is typified by planar to undulose thin bedding, bioturbation and lenses and beds of intraformational breccias. Gutter casts, small ripple marks and dolomite- and quartz-lined vugs also occur in the dolostone. Above this member, the succession becomes somewhat more variable with dark gray shale and mudstone and yellow weathering, thinly bedded and stromatolitic, pale gray shaly dolostone intercalated with the bioturbated and intraclastic dolostone already described. Desiccation cracks, lamination, flaser bedding, tepee structures and some cryptalgal structures occur in these beds. The stromatolitic structures consist of cryptalgal laminites and broad, low elevation mounds composed of closely spaced, laterally linked hemispheroids. Inarticulate brachiopods including *Lingulella* are common in the formation but so far the March Point Formation in the map area has not yielded any trilobites.

The conformably overlying Petit Jardin Formation is generally poorly exposed in the map area although it underlies much of the area south of Port Saunders Fault. It contains yellow to buff weathering, pale gray dolostone, minor limestone and red, green and gray shales and mudstones. A section on the south shore of Hawkes Bay reveals a 32 m thick basal member of red, green and gray shales intercalated with thinly bedded dolostone. Lamination, ripple marks, fenestrae, thin layers of intraclastic breccia and abundant desiccation cracks are common sedimentary structures. Cryptalgal structures in the member are generally irregular and oval shaped, broad, flat to centrally depressed, and surrounded by deep desiccation cracks.

Above the basal member, the succession includes thick beds of intraformational breccia, large stromatolite mounds, and cross-stratified oolitic grainstone as well as thinly bedded, shaly dolostone that exhibits flaser bedding, mudcracks and ripple marks. Limestone occurs within the dolostone in this member and has yielded the trilobite genera *Arapahoia* and *Blountia* and inarticulate brachiopods, possibly *Dicellomus*. These faunae confirm that the rocks are of early Late Cambrian age, and the trilobites indicate the Cedaria-Crepicephalus Zones.

The rest of the formation is poorly known but appears to include a member of yellow weathering, thick and thin bedded, pale gray dolostone which exhibits attributes of intertidal deposition, and includes some beds of cross-stratified, sandy dolostone with mudcracked dolostone drapes. Black chert nodules are common in the upper 180 m of the formation where thick beds of dark gray, finely crystalline dolostone exhibit stromatolite structures and bioturbation, and are interbedded with pale gray dolostone similar to that in the rest of the formation.

St. George Group

Sitting conformably above the Cambrian rocks are limestones, dolostones and diagenetic dolostones of the St. George Group; this group is divided into the Watts Bight, Boat Harbour, Catoche and Aguathuna Formations.

The basal Watts Bight Formation (WB, Figure 1) is approximately 100 m thick. It tends to form ridges and is fairly well exposed. The dark gray to black, fine to medium crystalline, diagenetic dolostone of the formation is generally cherty and characterized by light gray to creamy white mottling. The dolostone forms thick beds that exhibit large boundstone mounds including stromatolite structures that are intercalated with and surrounded by moderately to intensely bioturbated, generally thinly stratified carbonate. Thin (10 cm) interbeds of laminated and flaser bedded, dark gray dolostone with desiccation cracks occur locally. Intercrystal and cavity porosity lined by dolomite spar and frequently filled by pink to buff colored, geopetal dolomite mudstone also occurs. Ghosts of planispiral gastropods and straight ellesmeroceratid cephalopods indicate an Early Ordovician age for the formation.

A succession of partly dolomitized limestones on James Island in St. John Bay may belong to the Watts Bight Formation. The succession exhibits cryptalgal mounds and extensively developed, bioturbated, sparsely fossiliferous, well bedded limestones of subtidal origin. The presence of some trilobite fragments, possibly *Hystricurus oculilunatus* Ross, suggests that the succession may be equivalent to the Boat Harbour Formation.

The overlying Boat Harbour Formation (BH, Figure 1) is generally recessively weathering and not well exposed except along shoreline sections. The formation is approximately 150 m thick and is best exposed near Eddies Cove West and on Fox Islands in St. John Bay. The base of the formation is well exposed on Round Head Island where thick, mounded beds of white weathering, gray dolostone that are locally brecciated rest sharply upon burrow-mottled, dark gray dolostone of the Watts Bight Formation. Similar stratigraphic relationships occur elsewhere in the map area (see Knight, 1983).

The formation, which is characterized by deposits of peritidal settings, contains cyclically intercalated subtidal limestone, stromatolitic and thrombolitic lime boundstone and intertidal-supratidal limestone and dolostone. A disconformity is believed to interrupt the sequence close to the top of the formation. Diagenetic dolostone has replaced limestones in the lower 50 m of the formation where stratiform breccias also occur. These breccias occur in this same stratigraphic interval throughout the area but it is presently unclear if they are of sedimentary collapse (after the dissolution of limestone?) or of tectonic origin. The formation and its fauna in the area are described more fully in previous reports (Knight, 1983; Boyce, 1983).

Well bedded, fossiliferous, bioturbated, gray limestone which displays extensive, dolomitic burrow-mottling comprises the Catoche Formation (C, Figure 1). This distinctive and fairly well exposed unit, which is approximately 160 m thick, rests conformably upon the Boat Harbour Formation and commonly forms ridges in the area. Several beds of thrombolitic boundstone mounds also occur in the formation which was deposited generally in an open subtidal shelf environment. Bituminous, vuggy, light to dark gray diagenetic dolostone (d, Figure 1) extensively replaced limestone (though depositional fabrics are still preserved) of the upper 34 to 50 m of the Catoche Formation. It locally possesses high porosity and is rich in sparry dolomite within open spaces (pseudobreccia). Mapping suggests that the diagenetic dolostone passes laterally into insignificantly altered dolomitic limestone in the area north of River of Ponds Lake. A more detailed description of the Catoche Formation in the area is given by Knight (1977, 1983).

Overlying the Catoche Formation in the area mapped is the poorly exposed and recessively weathering Aguathuna Formation (A, Figure 1). This unit is composed of yellow weathering, siliceous and argillaceous dolostone which was deposited in restricted intertidal and supratidal flat settings. Collapse breccias were noted locally in the map area. The Aguathuna Formation as defined here is somewhat different from that described by Knight (1983), who combined a lower dolostone sequence with an overlying sequence of interbedded limestone and dolomitic limestone or dolostone in the formation. Rather, the formation is now confined to Knight's lower dolostone sequence only and the overlying strata are now placed in the Table Head Group.

At Port au Choix and Horn Island, St. John Bay, the dolostones appear to overlie diagenetic dolostones of the Catoche Formation conformably. The Aguathuna Formation in each locality is only 3.5 to 4 m thick; this thin sequence is in marked contrast to the approximately 57 m that occur in the formation at Table Point (Bellburns map area), 40 km to the south. Preliminary studies suggest that only the topmost beds in the Table Point section occur at Port au Choix. These facts combine to indicate that there may be a major facies change from northwest to southeast involving limestone of the top of the Catoche Formation passing southward into dolostone of the Aguathuna Formation. Alternatively, the same features suggest that a disconformity separates the Catoche and Aguathuna Formations at Port au Choix and that the disconformity occurs somewhere within the Aguathuna Formation in the Table Point section. If a disconformity is present, the lower Paleozoic platform in western Newfoundland was topographically uneven when the Aguathuna Formation was deposited.

Although no evidence of erosion occurs at the contact of the two formations in the map area, there is evidence that the platform was then being dissected by high angle northeast trending faults. In the Port Saunders map area, near Hawke Point, minor northeast trending faults and fractures cut the Catoche Formation. Buff weathering, dolomite-cemented sandstones which are composed of chert and vug-quartz sand grains and which exhibit good stratification and cross-stratification fill open spaces along the faults. These cemented sandstones are cut by shears indicating later fault movements (Figures 2 and 3). In the same area at Hawke Flat, eastward dipping fractures (Figure 4) were dilated by stresses or solution and are now filled by buff weathering, silty dolomite mudstone. Although there is no conclusive evidence that the fracture-fills are of Early Ordovician age, they nonetheless appear to be lithologically very similar to argillaceous dolostones and sandy dolarenites that contain vug- and chert-quartz sand grains in the Table Point section of the Aguathuna Formation. This interpretation of the fracture-fills as late Early Ordovician in age supports the hypothesis that the Early Paleozoic platform was deformed by a phase of block-faulting during the depositional time interval of the Aguathuna Formation and that a disconformity must lie between the diagenetic dolostones of the Catoche Formation and the overlying thin sequence of dolostones of the Aguathuna Formation at Port au Choix.

Table Head Group

Shoreline to subtidal shelf limestones of the Table Head Group (TH, figure 1) rest conformably upon the dolostones of the Aguathuna Formation in the map area. In the Port au Choix area, the basal 12 m of the formation consists of cyclically developed, burrow-mottled, fossiliferous lime mudstone and laminated, commonly mudcracked, fenestral dolostone or dolomitic lime mudstone previously assigned to the Aguathuna Formation by Knight (1983). Similar strata, approximately 9 m thick, were noted by Knight (1977) at the base of the Table Head Group at its type section at Table Point. Cross-stratified limestone occurs in the member at Gargamelle Cove. In the River of Ponds area, thickly bedded (1-2 m), white to light gray weathering, gray fenestral limestone occurs in which laminar and tubular fenestrae of variable dimensions are filled by geopetal muds and dolomite and calcite. These beds underlie a wide area to the north of River of Ponds and may be of substantial thickness. They may be in part equivalent to and/or overlie the basal member. Both cyclical and fenestral carbonates are overlain by the well bedded, blue gray fossiliferous, rubbly weathering limestone which is so characteristic of much of the Table Point type section. Slump breccias are common in this limestone near Port au Choix. Surprisingly, diagenetic dolostone described earlier by Knight (1983) has a wide distribution within the limestones of the Table Head Group. Some of the dolostone is sparry dolomite-rich pseudobreccia generally claimed to be restricted to the St. George Group.

Structure

Long, curvilinear, frequently braided and anastomosing, northeast to north trending faults transect the map area. The faults offset the stratigraphic boundaries to the northwest of the faults by many kilometres both southwestward and northeastward. Vertical throws of 100 to 1500 m occur across several of the faults. Grenvillian basement rocks of the Long Range Mountains are uplifted upon the north trending, eastward dipping Lady Worcester Brook Fault (LWBF). Dip of the fault planes varies from 55° to 90° and changes direction along the trace of the faults. Sense of vertical displacement varies across the map area. Rocks are downthrown to the northwest on the Ten Mile Lake (TMLF), Port Saunders (PSF) and Big East River (BERF) Faults but to the southeast on the Torrent River (TRF) and Starvation Ridge (SRF) Faults.

The faults are sharp, smooth planar surfaces in many outcrops but fault breccias a few metres wide are locally developed and carbonate rocks are extensively dolomitized close to faults. Strata between faults are either gently inclined and consistent in strike or gently warped about northeast trending, generally southwest plunging fold axes. However, close to faults, beds may dip steeply and be overturned; tight, locally recumbent, folds also occur, for example, the Big East River Fault on the north shore of Hawkes Bay. Stratigraphically exotic, structurally emplaced blocks of strata that are discordant to the structural grain, occur locally along the Torrent River and Starvation Ridge Faults. Axes of tight, northeast-trending folds close to the Whale Factory Pond, Big East River, Torrent River, and Starvation Ridge Faults strike obliquely at an angle of 25° into the faults. At several localities, for example, Two Hills Point near Port Saunders and the eastern shore of Western Brook Pond, drag folds within the downthrown, younger rock unit adjacent to the faults suggest the sense of displacement upon the faults is opposite to that normally associated with simple vertical movements. A north trending cleavage is locally developed in limestones of the Table Head Group and Catoche Formation within the braided fault system.

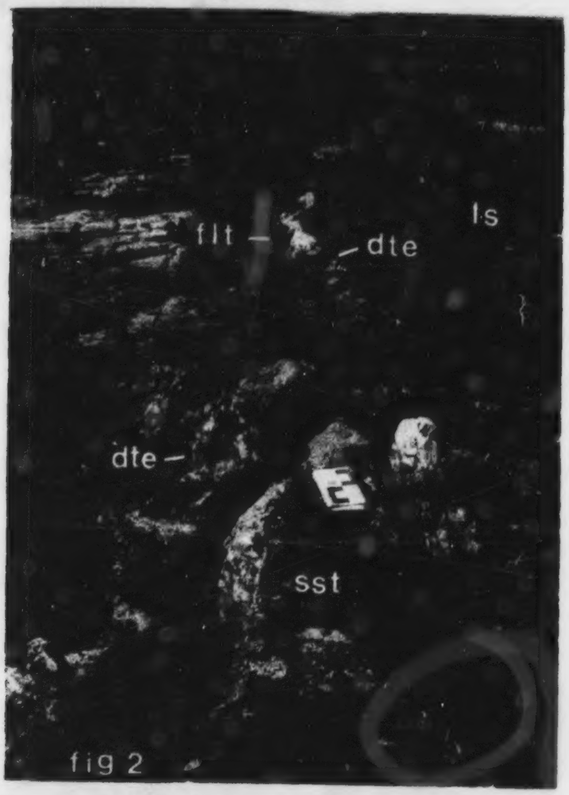

fig 2

fig 4

fig 3

Figures 2, 3 and 4: Northeast trending fault (flt) cutting limestones (ls) of the Catoche Formation at Hawke Point, Hawkes Harbour. Preserved along the fault are pockets of cemented quartz sandstone (sst, Figure 2) which displays depositional layering (Figure 3). Two fractures obliquely crosscut and displace this layering (arrows). Dolostone (dte) replaces the limestone in a narrow zone close to the fault plane. Three kilometres to the east at Hawke Flat, Hawkes Bay, dolomite mudstones fill easterly dipping joints that also cut rubbly weathering, well bedded limestones of the Catoche Formation (Figure 4). These structures and sedimentary fills are believed to support the hypothesis of a phase of block faulting on the carbonate platform during the late Early Ordovician.

Although large vertical displacements have occurred on the faults and reverse faulting likely occurred on the Lady Worcester Brook Fault, variable bedding attitudes and fold styles, fold trends oblique to faults, anomalous senses of displacement upon the faults suggested by the folds, and the presence of exotic structural blocks along the trace of some faults all suggest that a major strike-slip component of movement occurred upon the faults. The orientation of drag folds close to the Big East River, Port Saunders and Torrent River Faults suggests right lateral movements occurred. No structural evidence has been found to date, however, to suggest that a phase of sinistral strike-slip movement also affected the platformal strata even though left lateral offset of stratigraphic markers occurs across the Torrent River and Starvation Ridge Faults.

Mineralization

Minor sphalerite, galena, chalcopyrite, barite and fluorite showings occur in the map area.

Sphalerite, galena and barite occur in rocks of the Port au Port Group. Traces of an earlier presence of disseminated sphalerite in dolostone of the March Point Formation was revealed using a zinc reactive solution. Weathered sphalerite crystals were subsequently noted in outcrops west of Otter Pond and on a woods road 6 km north of Eastern Blue Pond.

The best known Cambrian showing in the area is that near Pikes Feeder Pond (Beckett, 1966) where galena, sphalerite and associated chalcopyrite and pyrite occur in gray, massive dolostone of the lower Petit Jardin Formation. The mineralization is mostly in open spaces along an irregular fracture network so that galena, the dominant mineral, occurs as fine streaks, and as coarse, 5 mm crystals and massive clots within fracture porosity. However, coarse crystalline galena also appears to concentrate in layers parallel to bedding, locally disseminated in intercrystal porosity, and as small clots and laminae associated with green and yellow sphalerite within and possibly replacing the depositional fabric of the original dolostones. Beckett (1966) suggested that the mineralization is essentially stratabound although related to a north trending, steeply eastward-dipping fracture zone. Mineralization was traced over a strike length of 1200 m by trenching and soil and stream geochemistry. Trenching showed that galena is distributed over a thickness of 60 cm and Beckett (1966) estimated that this width contained an average of less than 2% galena although locally galena is more concentrated.

Barite occurs in dolostones of the Petit Jardin Formation at the upper end of Indian Steady, near Middle Pond. The long, bladed, white crystals were precipitated in open cavities that had previously been lined by sparsely developed crystals of rhombic dolomite.

In the St. George Group, mineralization occurs in the Boat Harbour and Catoche Formations. Fluorite occurs as disseminated crystals and in spherical vugs in limestone and dolostone of the Boat Harbour Formation just north of Eddies Cove West. Shearer (1964) and Beckett (1966) reported sphalerite, pyrite and marcasite towards the base of the Boat Harbour Formation on the shore, 3 km north of the same community. The showing has not been located. Beckett (1966) describes black and pale brown sphalerite surrounding marcasite in nodules in a north-trending, steeply dipping vein up to 6 inches (15 cm) in width. A marcasite-pyrite showing occurs in possible collapse breccias at the base of the Boat Harbour Formation on Round Head Island, St. John Bay. The pyrite fills fracture porosity in the breccia, surrounding dolostone fragments. Locally, massive and nodular marcasite is developed in the breccia.

A galena, sphalerite and pyrite showing (called the Rice Pudding Showing) with a strike length of several metres occurs in calcite, dolomite and quartz veins that cut dolomitized limestone of the Catoche Formation on the northwest shore of River of Ponds Lake. The galena and sphalerite, forming streaks in fine fractures and locally fist-sized clots, occur with aggregates of crystalline black sphalerite that grew upon sparry dolomite that had already lined the fracture walls. A minor, north trending, vertical fault cuts the carbonates along the shore to the north of the showing. Secondary, crystalline dolostone, associated with the showing, replaces, fossiliferous limestone and cryptalgal mounds. It is white and pink in color, equigranular in texture and highly porous. The pink dolostone contains unseen zinc mineralization since the rock reacts to the application of zinc reactive solution.

Three sphalerite-galena showings were found in epigenetic? dolostone that replaces limestone low in the Table Head Group on St. John Island. The mineralization, which is locally associated with pyrite and barite, occurs in large tabular bodies to irregular stockworks of gray, crystalline dolostone that replace the limestone where the limestone is gently warped and cut by minor faults. Sparry dolomite lines open spaces. Dark brown, very coarse crystals of sphalerite and disseminated and aggregated crystals of galena occur along the margins, in shear zones, and as open space fillings along bedding planes and within beds of the dolostone. The dolostone is strongly petroliferous and black hydrocarbon residues fill some open spaces in the mineralized dolostone.

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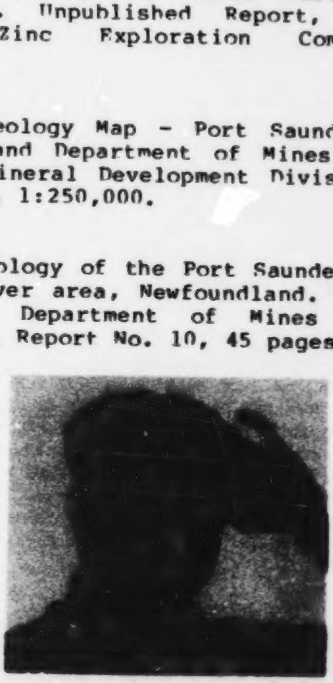

Ian Knight

DOLOMITES AND DOLOMITIZATION OF THE LOWER ORDOVICIAN ST. GEORGE GROUP OF WESTERN NEWFOUNDLAND[1]

Douglas W. Haywick and Noel P. James[2]

Haywick, D.W. and James, N.P., Dolomites and dolomitization of the Lower Ordovician St. George Group of western Newfoundland; in Current Research, Part A, Geological Survey of Canada, Paper 84-1A.

Abstract

Dolomite makes up approximately one third of the carbonates in the St. George Group of western Newfoundland and six varieties are now recognized.

Dololaminites are ubiquitous, composed of very fine crystals, characteristically laminated and thought to have been formed in shallow marine to supratidal environments. Intramuros dolomite preferentially replaces trace fossil walls as well as certain fossilized shells, is concentrated along stylolites, and is responsible for the dolomitic mottling so prevalent within the St. George Group. Pervasive dolostone is also mottled, but is the result of two different types of dolomite, one with finer crystallinity than the other. Matrix dolomite replaces carbonate mud between allochems and burrows and when extensive, expands to replace the whole rock. Cavity-filling dolostone is finely crystalline and has filled dissolution cavities or voids within pre-existing dolostone and may be related to unconformities. Saddle dolomite fills late stage fractures and voids and in combination with pervasive dolostone, is responsible for "pseudo breccia" beds associated with economic deposits of sphalerite.

Dololaminites are the earliest, probably synsedimentary, dolostones whereas saddle dolomite, because it cuts across most other varieties, is clearly the latest. The fact that saddle dolomite is restricted to areas in the northern portion of Great Northern Peninsula implies that this area was affected by a later dolomitization event which did not occur in more southern regions.

Résumé

La dolomite forme environ le tiers des carbonates dans le groupe de St. George de l'ouest de Terre-Neuve; on en reconnaît actuellement six variétés.

Les laminites dolomitiques sont omniprésentes; composées de cristaux très fins, elles ont des laminations caractéristiques et se seraient accumulées dans des milieux marins allant de peu profonds à supratidaux. La dolomite intra-muros remplace de préférence les murs des empreintes fossiles ainsi que certains coquillages fossilisés; elle est concentrée le long de stylolites et cause le mouchetage dolomitique si commun dans le groupe de St. George. La dolomie pénétrante, également mouchetée, est produite par deux types différents de dolomite, l'une plus fine que l'autre. La dolomite matricielle remplace la boue carbonatée entre les allochèmes et les terriers; lorsqu'elle se présente en vastes quantités, elle prend de l'expansion et remplace la roche entière. La dolomie de remplissage est finement cristalline et remplit les trous ou les vides laissés par le processus de dissolution dans les dolomies déjà existantes; elle pourrait être liée à des discordances. La dolomite anticlinale remplit des fractures et des vides récents et, conjugué avec la dolomie pénétrante, est à l'origine des lits de pseudobrèches associés aux gisements économiques de sphalérite.

Les laminites dolomitiques, de nature vraisemblablement synsédimentaires, sont les dolomies les plus anciennes, tandis que la dolomite anticlinale est évidemment la plus récente, puisqu'elle recoupe la plupart des autres variétés. En raison du fait que la dolomite anticlinale est limitée à des régions dans le nord de la Grande presqu'île du Nord, il se peut que cette région ait subi une phase de dolomitisation plus récente qui ne se soit pas produite plus au sud.

INTRODUCTION

The Lower Ordovician St. George Group of western Newfoundland has been extensively studied over the past few years (Levesque, 1977; Knight, 1977a, b, 1978; Pratt, 1979; Smyth, 1982a, b, c) with the result that the stratigraphy, sedimentology, and paleontology of these rocks are relatively well documented. However, little is known about the dolomites which account for approximately one third of the St. George Group. The purpose of the study is threefold; to fully document the various textures exhibited by the dolomites, to determine their stratigraphic and geographic distribution, and to examine possible mechanisms to explain the modes of dolomitization. This preliminary report addresses the first two objectives.

The St. George Group outcrops semi-continuously along the west coast of Newfoundland from the Port au Port Peninsula in the south to Cape Norman in the north. Five sections were studied in the vicinity of the Port au Port Peninsula and a further four sections were studied at specific points along the Great Northern Peninsula during the summer of 1983. In addition, several key locations which contained interesting dolomite relationships, but where sections could not, or were not measured, were also investigated.

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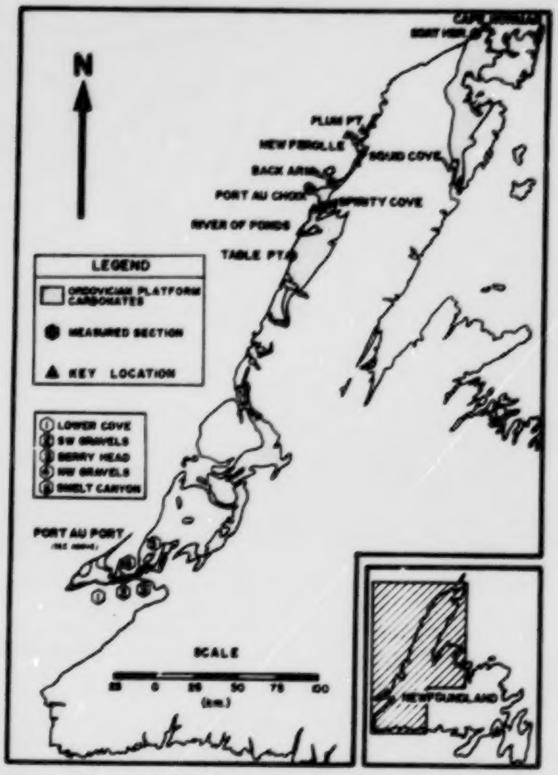
N
PLUM PT.
NEW FEROLLE
SQUID COVE
BACK ARM
PORT AU CHOIX
SPIRITY COVE
RIVER OF PONDS
TABLE PT.
LEGEND
ORDOVICIAN PLATFORM CARBONATES
MEASURED SECTION
KEY LOCATION
① LOWER COVE
② SW GRAVELS
③ BERRY HEAD
④ NW GRAVELS
⑤ SMELT CANYON
PORT AU PORT
SCALE
25 0 25 50 75 100
(km.)
NEWFOUNDLAND

Figure 1. Location map of Lower Ordovician platformal carbonate rocks along the west coast of Newfoundland. The position of measured sections and key locations investigated during this study are also indicated.

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GENERAL GEOLOGY AND STRATIGRAPHY

The Lower Ordovician St. George Group is part of the Cambro-Ordovician platformal sequence (the ancient continental margin of North America) that was assigned by Williams (1978, 1979) to the Humber Zone of the Newfoundland Appalachians (Fig. 1). Although the formational nomenclature has been modified extensively since Schuchert and Dunbar's pioneer work published in 1934, it is now generally agreed that the St. George Group can be subdivided into four formations (I. Knight and N.P. James, personal communication, 1983).

The lowermost unit, the Watts Bight Formation conformably overlies upper Cambrian peritidal and stromatolitic dolostones and is characterized by dark grey to black, vuggy and often cherty stromatolitic dolostone (Fig. 2). In some regions, particularly Hare Bay and possibly on Port au Port Peninsula, the Watts Bight Formation is a bioturbated and often fossiliferous mudstone to wackestone. This suggests that prior to dolomitization, the rocks of the Watts Bight Formation were subtidal shelf deposits (Knight, 1977a, b, 1978).

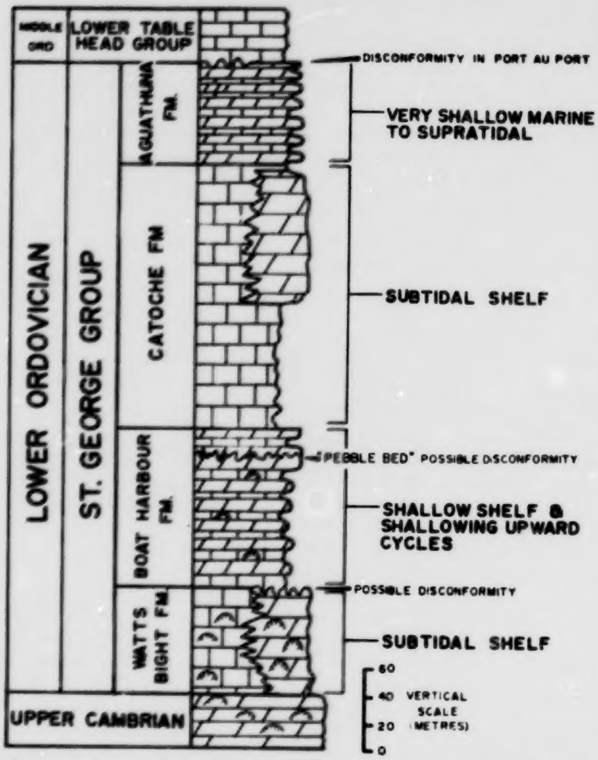

MIDDLE ORD
LOWER TABLE HEAD GROUP
LOWER ORDOVICIAN
ST. GEORGE GROUP
AGUATHUNA FM.
CATOCHE FM
BOAT HARBOUR FM.
WATTS BIGHT FM.
UPPER CAMBRIAN
DISCONFORMITY IN PORT AU PORT
VERY SHALLOW MARINE TO SUPRATIDAL
SUBTIDAL SHELF
"PEBBLE BED" POSSIBLE DISCONFORMITY
SHALLOW SHELF & SHALLOWING UPWARD CYCLES
POSSIBLE DISCONFORMITY
SUBTIDAL SHELF
60
40
20
0
VERTICAL SCALE (METRES)

Figure 2. Schematic stratigraphic section of the Lower Ordovician St. George Group. Proposed depositional environments (in heavy type) and the locations of disconformities within the St. George Group are summarized on the right side of the section. Coarsely crystalline dolomitization of parts of the Watts Bight and Catoche formations are indicated by the cross hatched pattern. (Data from Knight, 1977b, 1978).

A breccia bed, possibly indicating a disconformity, separates the Watts Bight Formation from the overlying Boat Harbour Formation along the Great Northern Peninsula (Knight, 1977b). This breccia bed appears to be somewhat localized as the contact seems conformable where exposed in the Port au Port area.

The Boat Harbour Formation is a series of thick bedded, bioturbated or laminated dolostones and thin- to thick-bedded stromatolitic and/or bioturbated limestones. Levesque (1977), Knight (1977a, b), and Pratt (1979) regarded this formation as being the result of repeated shallowing upward sequences.

A possible break in sedimentation near the top of the Boat Harbour Formation has been suggested by Knight (1978) and Pratt (1979) who cited a layer of chert pebbles and silicified ooids and intraclasts as evidence of an exposure surface. Locally referred to as the "pebble bed", this horizon appears to be of wide extent ranging from the Port au Port vicinity to Cape Norman (Pratt, 1979).

The Boat Harbour Formation is conformably overlain by the Catoche Formation, a bioturbated, fossiliferous mudstone to wackestone of which the faunal content suggests a predominantly subtidal depositional environment (Levesque, 1977; Knight, 1977a, b, 1978; Pratt, 1979).

Table 1. Summary of distinguishing characteristics and the proposed paragenetic sequence of the six varieties of dolomite and dolostone observed within the St. George Group

	DOLOMITE TYPE	CRYSTAL SIZE	COLOUR	PERCENT OF HOST ROCK	DISTINGUISHING CHARACTERISTICS	DISTRIBUTION	
						STRATIGRAPHIC	GEOGRAPHIC
EARLY	1) DOLO-LAMINITES	VERY FINE	BUFF to WHITE	100%	CONTAINS ABUNDANT SHALLOW WATER SEDIMENTARY STRUCTURES i.e. MUDCRACKS, PRISM CRACKS, LAMINATIONS	AGUATHUNA & BOAT HARBOUR FMS	WIDESPREAD
	2) INTRA-MUROS DOLOMITE	0.1 mm	BUFF to DOVE GREY	1% to 40%	SELECTIVELY REPLACES ICHNOFOSSIL WALLS AND SOME FOSSILIZED SHELLS CAN BE LOCALIZED ALONG STYLOLITES	WIDESPREAD	WIDESPREAD
	3) MATRIX DOLOMITE	0.1 mm	BUFF	5 to 100%	REPLACES CARBONATE MUD BETWEEN ALLOCHEMS AND ICHNOFOSSILS.	CATOCHE, BOAT HARBOUR & WATTS BIGHT FMS	PORT AU PORT
	4) PERVASIVE DOLOSTONE SUB-TYPE (A)	0.1 & 0.3 mm	MED. GREY	95 to 100%	FINER CRYSTALLINE DOLOMITE IS LOCALIZED IN ICHNOFOSSILS, FOSSILS AND GASTROPOD SHELL WALLS. COARSER CRYSTALLINE DOLOMITE OCCURS IN THE INTERAREAS BETWEEN THESE FEATURES.	WIDESPREAD	WIDESPREAD
	SUB-TYPE (B)	0.1 to 0.3 mm & 1.0 mm	MED. GREY to WHITE	100%		CATOCHE BOAT HARBOUR & WATTS BIGHT FMS	NORTHERN PENINSULA
	5) CAVITY FILLING DOLOSTONE	VERY FINE	BUFF	100%	TYPICALLY GEOPETAL, HAS FILLED DISSOLUTION CAVITIES AND VOIDS IN PRE EXISTING DOLOSTONE.	BOAT HARBOUR & WATTS BIGHT FMS	LOCALIZED OCCURRENCES PORT AU PORT & NORTHERN PENINSULA
LATE	6) SADDLE DOLOSTONE	0.5 to 15.0 mm	WHITE to PINK	100%	FILLS IN FRACTURES AND VOIDS WITHIN PRE EXISTING DOLOSTONE.	CATOCHE BOAT HARBOUR & WATTS BIGHT FMS	NORTHERN PENINSULA

North of Table Point (Fig. 1 1), much of the limestone of the Catoche Formation has been replaced by white, sparry dolomite. This dolomite is host to economic sphalerite mineralization in the Daniel's Harbour area.

The Aguathuna Formation conformably overlies the Catoche Formation and is the uppermost division of the St. George Group. A unit of interbedded finely crystalline and laminated dolostones, dolomitic shales and limestones, the Aguathuna Formation was probably deposited in a shallow water to supratidal environment much like the Boat Harbour Formation below (Levesque, 1977; Knight, 1978; Pratt, 1979).

The Aguathuna Formation is extremely variable in thickness. In the Port au Port area, the interbedded limestones and dolostones are a minimum of 50 m thick. Farther north at Table Point, the Aguathuna Formation is exclusively dolostone and is approximately 75 m thick (Levesque, 1977). Still farther north at Port au Choix, the formation is a mere 10 m thick and consists only of a few dolostone beds. The Aguathuna Formation does not seem to be present at all in the Cape Norman area.

This Lower Ordovician sequence is overlain by the Middle Ordovician Table Head Group whose basal limestones are thought to have been deposited in an intertidal to subtidal setting (Klappa et al., 1980). The contact between the St. George and Table Head groups has been well documented as a disconformity on the Port au Port Peninsula along which up to several metres of strata have been removed (Schuchert and Dunbar, 1934; Cumming, 1968). In recent years, however, the importance of this disconformity has been questioned, especially along the west coast of the Great Northern Peninsula where strata appear to be continuous across the boundary.

The basal limestones of the Table Head Group pass upwards into deep water carbonates, shales and finally flysch recording the collapse of the stable continental margin (Klappa et al., 1980).

TEXTURAL TYPES OF DOLOMITE AND DOLOSTONE

The various dolomites and dolostones within the St. George Group can be separated into six distinct types. At this stage of investigation, the principal distinguishing criteria are limited to dolomite crystal size, sedimentary structures and textural relationships. The characteristics of the six varieties of dolomite and dolostone as well as their approximate paragenetic sequence, are summarized in Table 1.

Type 1: dololaminites

Dololaminates are dolostones characterized by a very fine crystal size and numerous fine laminations (Plate 1) (Wanless, 1979). They contain an abundance of sedimentary structures which include mudcracks, prism cracks, tepees, small-scale crossbedding and flat-pebble breccias. Colourless or white chert is commonly present in dololaminites, either as individual nodules or in discontinuous horizons. Both ichnofossils and body fossils are noticeably absent.

Sedimentologial studies by Levesque (1977), Knight (1977a, b, 1978) and Pratt (1979) have concluded that these dolostones probably formed early in very shallow marine to supratidal environments.

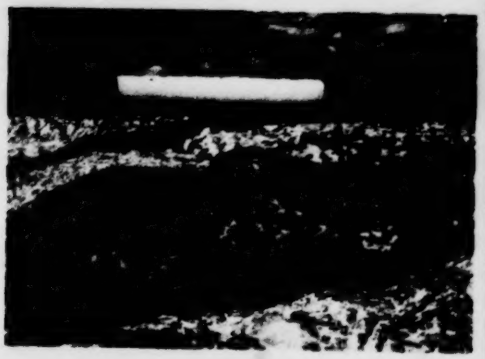
A common component of both the Boat Harbour and Aguathuna formations, dololaminites are widespread and are found in most sections and outcrops examined in this study.

Type 2: intramuros dolomite

The second textural type of dolomite is responsible for the mottling which is so common in most of the limestones within the St. George Group (Plate 1). The dolomite is finely crystalline and preferentially replaces trace fossils walls, the shells of some fossils, laminations and/or stylolites. Because of its affinity for burrow walls, this type of dolomite is referred to as intramuros (Latin for "within the walls").

A

B



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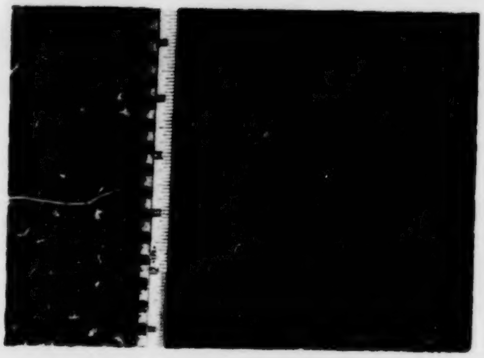

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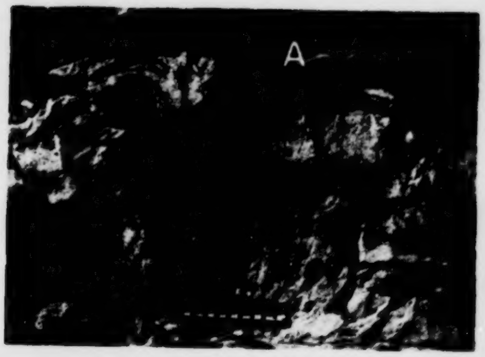

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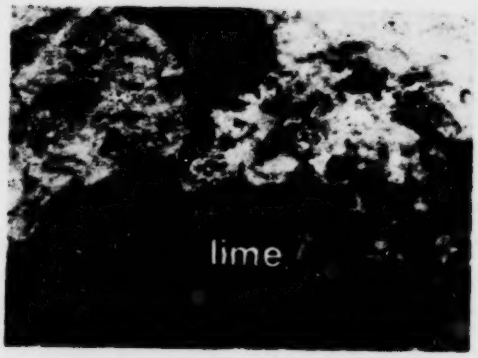

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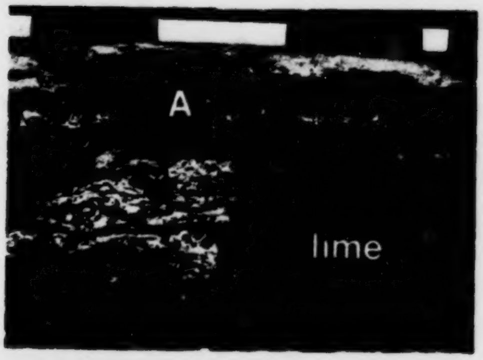

G

H

There are variable degrees of intramuros dolomite, ranging from instances of exclusive trace fossil-mottling to instances of exclusive stylolite-mottling. It is tempting to separate out several subtypes to account for the variability observed within this type of dolomite, but even within a single limestone bed, there are zones favouring one "subtype" over another, and consequently a complicated classification scheme for intramuros dolomite would probably cause more confusion than clarification. For the present time, therefore, intramuros dolomite will not be subdivided.

Plate 1

Various textures of dolomite and dolostone observed within rocks of the St. George Group

A. Dololaminites are characterized by a very fine crystal size and by shallow water sedimentary structures. This dololaminite from the Boat Harbour Formation on Port au Port Peninsula clearly shows prism cracks (arrow) and fine laminations.

B. Limestone mottled with buff coloured intramuros dolomite from the Boat Harbour Formation, Port au Port. The white portion of the scale bar is 25 cm long.

C. Bedding plane view of the intramuros dolomite displayed in B. The dolomite is localized within gastropod shell walls (arrow) and ichnofossils.

D. Matrix dolomite, unlike intramuros dolomite, does not preferentially replace trace or body fossils so that often the original fabric of the rock is lost. In some instances however, such as this example from the Aguathuna Formation in the Port au Port area, dolomite (labelled A) replaces the matrix between stromatolites but not the stromatolites themselves. As a result, part of the original fabric is preserved.

E. Pervasive dolostone, subtype A (labelled A) in contact with a limestone containing intramuros dolomite (labelled lime) within the Watts Bight Formation, Port au Port. Weak mottling within the dolostone is due to the presence of two crystal sizes; finer dolomite being localized within ichnofossils and coarser dolomite being localized between ichnofossils. The camera lens cap is 6 cm in diameter.

F. Pervasive dolostone, subtype A (labelled A) in contact with pervasive dolostone subtype B (labelled B) and limestone (labelled lime) within the Catoche Formation, Cape Norman. The two subtypes of pervasive dolostone can be distinguished from one another by the appearance and crystal size of the dolomite that occupies the interareas between ichnofossils. The dolomite within the interareas in subtype B is usually much lighter in colour and more coarsely crystalline than that found between ichnofossils in subtype A. Scale bar divisions are 25 cm across.

G. Cavity-filling dolostone (arrow) is typically geopetal and infills voids or cavities within pre-existing dolostone. This example occurs within a stromatolite-rich portion of the Watts Bight Formation near Boat Harbour. The field book is 19 cm across.

H. Saddle dolomite is the latest phase of dolomite observed in the St. George Group. It is localized within fractures and veins that cut across most of the other varieties of dolomite and dolostone. This example is from the Catoche Formation, Table Point.

It is unclear at this time as to the role stylolites have played in the development of intramuros dolomite. Some clearly have acted as zones where dolomitization was initiated (Wanless, 1979), but many also appear to have simply entrapped the more resistant dolomite rhombs during periods of pressure solution. The role that ichnofossils and some shells (especially gastropods) have played is more straightforward. Dolomitization was initiated in the walls of the ichnofossils and shells and spread both inward and outward into the neighbouring limestone once the walls had been completely replaced. This dolomitization occurred relatively early in the diagenetic history of the rock, but probably postdates the event responsible for the dololaminites. This is evidenced by field relationships observed in and between the two dolomite varieties.

The percentage of intramuros dolomite within a host limestone reflects both the intensity of bioturbation and the degree of replacement of the trace fossils. Proportions range from trace quantities to approximately 40 per cent and average overall to approximately 10 per cent.

Intramuros dolomite is widespread, both stratigraphically and geographically. It is present in particularly every limestone bed in every formation of the St. George Group and in all outcrops studied.

Type 3: matrix dolomite

Type 3 is best described as matrix-selective dolomite (Plate 1). In packstone and grainstone beds, finely crystalline dolomite rhombs can often be observed replacing the matrix between grains, but not the grains themselves. In the finer grained mudstones and wackestones, dolomite rhombs are randomly distributed over the entire volume of the bed.

Primarily features such as trace fossils are not preferentially dolomitized, and thus commonly a great deal of the original fabric is lost. Occasionally, however, matrix dolomite will selectively replace some parts of a limestone over others with the result that some of the original fabric (usually stromatolitic) is preserved.

Dolomite-mottled stylolites are present in finer grained limestones containing matrix dolomite, but they do not appear to be directly responsible for the dolomitization. They have more likely entrapped dolomite rhombs during a period of pressure solution. Stylolites do, however, tend to mark boundaries between regions of higher and lower proportions of matrix dolomite. This variability can be intense, ranging from approximately 5 per cent to close to 100 per cent within a single bed.

Matrix dolomite probably developed early in the diagenetic history of the rocks. Exact timing is not yet possible, however, on the basis of similar crystal size and field relationships, it is likely that this type of dolomite formed at about the same time as intramuros dolomite.

Matrix dolomite is not abundant in the St. George Group being restricted to the limestones of the Watts Bight, Boat Harbour, and Aguathuna formations in the Port au Port area only.

Type 4: pervasive dolostone

Pervasive dolostone is composed of two generations of dolomite, each generation being characterized by a distinct crystal size. Superficially, this bimodal distribution has resulted in a mottled appearance to the rock.

Two subtypes of pervasive dolostone are recognized within the St. George Group (Plate 1). In both cases, finer dolomite is localized within ichnofossils, stylolites and gastropod shell walls, much the same as intramuros dolomite. However, unlike intramuros dolomite where interareas between ichnofossils, stylolites, and gastropod shell walls are undolomitized, the interareas in pervasive dolostone have been dolomitized. The two subtypes of pervasive dolostone can be distinguished from one another by the nature of the dolomite crystals that occupy these interareas. In subtype A, the crystals are medium grey and are finely crystalline. In subtype B, the crystals within the interareas are white to pink and are coarsely crystalline.

Both varieties of pervasive dolostone are common components of the Watts Bight, Boat Harbour and Catoche formations, but differ in their geographic distribution. Subtype B is found only in areas north of Table Point, whereas subtype A is widespread. Textural evidence suggests that subtype B is the result of a dolomitization event later than the one responsible for subtype A. The fact that subtype B is restricted to the Great Northern Peninsula implies that the northern part of the study area was subjected to a late phase of dolomitization which did not affect more southerly areas.

Type 5: cavity-filling dolostone

This dolostone is best described as cavity-filling (Plate 1). It occurs in small (less than 30 cm), irregularly shaped cavities within preexisting pervasive dolostone and is finely crystalline, faintly laminated and usually geopetal.

Towards the top of the Boat Harbour Formation on Port au Port Peninsula, cavity-filling dolostone occurs immediately beneath the pebble bed, which has been interpreted as a possible exposure surface (Knight, 1978; Pratt, 1979). There are also several occurrences of cavity-filling dolostone within the pervasive dolostones of the Watts Bight Formation in the Boat Harbour and New Ferolle areas. It is unclear, however, whether or not these occurrences are due to as yet undiscovered disconformities.

Type 6: saddle dolomite

The sixth phase of dolomitization is responsible for the white to pink, very coarsely crystalline and typically saddle-shaped dolomite crystals found exclusively north of Table Point. Saddle dolomite is associated with pervasive dolostone and usually occurs in fractures and veins cutting across the host rock (Plate 1). It may also replace the finely crystalline dolomite which marks trace fossils and stylolites in the pervasive dolostone.

In localities where saddle dolomite fractures or veins cut across limestones, there does not seem to be any "dolomite aureole" penetrating the surrounding limestone. It appears then, that this variety of dolomite did not itself cause dolomitization, but simply infilled open fractures. Therefore, saddle dolomite can be thought of as "void-filling."

Saddle dolomite, when associated with the pervasive variety, often develops the texture locally referred to as "pseudobreccia" and it is this pseudobreccia which is associated with sphalerite mineralization in the Daniel's Harbour area of western Newfoundland.

The event, which is responsible for the emplacement of saddle dolomite, is clearly the latest one in the diagenetic history of these rocks. This is evidenced by the fact that saddle dolomite veins cut across most other varieties of dolomite and dolostone. Dololaminites on the other hand are products of the earliest phase of dolomitization. The other varieties formed between the period of time marked by these two end members, probably in the order discussed in this report and summarized in Table 1.

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PRELIMINARY CLASSIFICATION OF CARBONATE BRECCIAS, NEWFOUNDLAND ZINC MINES, DANIEL'S HARBOUR, NEWFOUNDLAND

by

Thomas E. Lane[1]

Abstract

Zinc ore at Newfoundland Zinc Mines is strata-bound in dolostone within the upper third of the Lower Ordovician Catoche Formation (St. George Group) of the Humber Zone in western Newfoundland. Five types of breccias associated with zinc ore are distinguished in a preliminary classification.

Intraformational breccias, strata-bound units of the Aguathuna Formation, represent disconformities or early diagenetic dissolution surfaces associated with the transition from subtidal to supratidal lithofacies. Fine rock matrix breccias associated with pre-Middle Ordovician structural depressions are divided into two types: oligomictic breccias formed by strata-bound dissolution, and polymictic breccias accumulated in vertical dilation openings along the margins of structural depressions. White spar breccias that host the zinc ore are characterized by open fracture and cavity systems filled with megacrystalline white dolomite. True spar breccias occur where strata are broken by faulting, veining or dissolution. Elsewhere, pseudobreccia represents in situ *replacement by white dolomite.*

Introduction

Zinc ore deposits of Newfoundland Zinc Mines, Daniel's Harbour, are hosted in dolostone of the upper St. George Group (Lower Ordovician) in western Newfoundland (Figure 1). Several types of breccias are related to zinc ore as both gangue and associated rocks, but their nature and interrelationships are poorly understood. The genesis of the breccias is directly related to the origin of the zinc ore of this and other Mississippi Valley type deposits. A preliminary classification of breccias and their relationship to zinc ore is presented as a first step towards understanding this genesis.

This study is an extension of previous studies carried out at the site. Collins (1971) and Collins and Smith (1975) recognized a variety of features that suggested ground preparation by karst. Dillon (1978) analyzed the rock geochemistry. Coron (1982) studied ore genesis from host rock petrography and isotope geochemistry, and developed models for ground preparation by evaporite dissolution, and generation of ore fluids along faults.

Regional Geology

The Daniel's Harbour deposit is located within autochthonous rocks in the

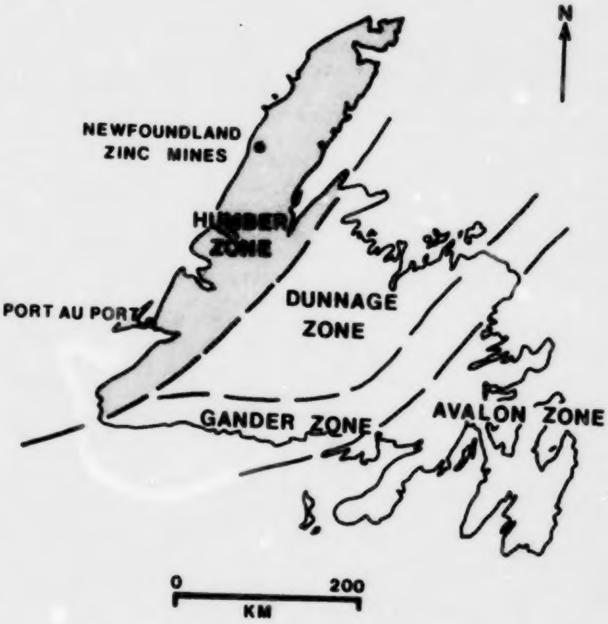

Figure 1: *Tectonostratigraphic zones of Newfoundland with the location of Newfoundland Zinc Mines (after Williams, 1979).*

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Humber tectonostratigraphic zone (Williams, 1979), which is interpreted to be the ancient continental margin of North America on the western margin of the Cambro-Ordovician Iapetus Ocean (Figure 1). A Lower Cambrian to Lower Ordovician succession of shallow water siliciclastic and carbonate rocks overlie Precambrian Grenville basement. The autochthonous rocks are partly covered by easterly derived thrust slices of deep marine strata and ophiolites, which were emplaced during the Taconic Orogeny (Middle Ordovician). The autochthonous rocks are relatively undeformed and unmetamorphosed. However, some strata are displaced up to 1500 m by faults striking 020° to 060°, and tilted into a series of westerly dipping monoclines along these faults.

A stable shallow marine platform existed in the Humber Zone from Early Cambrian through Early Ordovician time (Knight, 1977; Levesque, 1977; Pratt, 1979; James and Stevens, 1982). During the late Precambrian - Early Cambrian, the North American continental margin became an area of sediment accumulation following postrift downwarping. By Middle Cambrian time, an extensive shallow water carbonate platform had been established. Middle to Upper Cambrian formations (March Point and Petit Jardin Formations) comprise muddy and sandy carbonates, deposited in tidal flats and sand shoals (Levesque, 1977; Figure 2). During Early Ordovician time, widespread subtidal conditions existed on the platform, resulting in abundant mudstone accumulation (James and Stevens, 1982).

The St. George Group is divided into four formations (Knight and James, personal communication, 1983), namely the Watts Bight Formation (80 m thick) which is overlain by the Boat Harbour Formation (120 m thick), the Catoche Formation (200 m thick), and the Aguathuna Formation (60 m thick) (Figure 2). The Boat Harbour and Aguathuna Formations are similar lithologically; both consist of cycles of intercalated subtidal limestone, mottled dolostone, and supratidal planar laminated, in places mudcracked, dolostone (Pratt, 1979). The intervening Catoche Formation consists of thick sections of dark gray, fossiliferous subtidal limestone. Mottled, peloidal mudstone and wackestone of the upper third of the Catoche Formation mark upward shoaling into an intertidal regime. This upper third of the Catoche Formation is complexly dolomitized, characterized by abrupt diagenetic fronts, breccias, and megacrystalline (1 mm) white dolomite which hosts the zinc ore.

The transition from the Aguathuna Formation to the Middle Ordovician Table Head Group is marked by one or more disconformities. Stouge (1982), using conodonts, recognized a biostratigraphic break and possible lacuna 10 m above the base of the Aguathuna Formation. Another discontinuity with 16 m of erosional relief occurs between the Aguathuna and Table Point Formations near Port au Port, Newfoundland (Figure 1). At Daniel's Harbour, strata above this particular horizon fill paleotopographic depressions generated by solution collapse, faulting, or both (Figures 3 and 4). These disconformities are equivalent to the Knox-Beekmantown unconformity of the central and southern Appalachians (Rodgers, 1971; Mussman, 1982).

During Middle Ordovician time (White Rock Stage), widespread subtidal conditions were re-established on the platform as recorded by the limestones of the Table Head Group (Klappa et al., 1980). Near the end of Table Head Group deposition, the platform rapidly subsided and ribbon limestones, shale, carbonate debris flows, and turbidites were deposited. These were covered by an easterly derived siliciclastic flysch and, finally, tectonically emplaced ophiolitic allochthons. Subsequently, the Grenville basement was uplifted and the cover rock was broken into a series of subparallel fault zones and monoclines.

From this regional overview, it is apparent that several environmental conditions may have influenced the formation of the breccias: (1) shoaling on the carbonate platform during St. George Group deposition; (2) overlying disconformity with a local erosion surface and collapsed paleotopography (the St. George - Table Head break); (3) subsequent tectonic downwarping of the platform prior to allochthon emplacement; and (4) faulting during uplift of the Grenville basement.

Stratigraphy and Geometry of the Ore and Host Rocks

In the vicinity of the mines at Daniel's Harbour, the sphalerite ore is stratigraphically and lithologically restricted to megacrystalline (1 mm crystal size) dolostones of the upper third of the Catoche Formation. This part of the Catoche Formation has been complexly dolomitized, and only 25% of it remains unaltered limestone. The major dolostone types include: (1) an assemblage of intercalated strata of megacrystalline (1 to 5 mm) white dolomite and fine crystalline (0.01 mm) gray dolomite and white dolomite veins, comprising 50% of the upper Catoche Formation; (2) 20% pervasive coarse crystalline (0.1 to 1 mm) vuggy gray dolomites; and (3) 5% gray fine

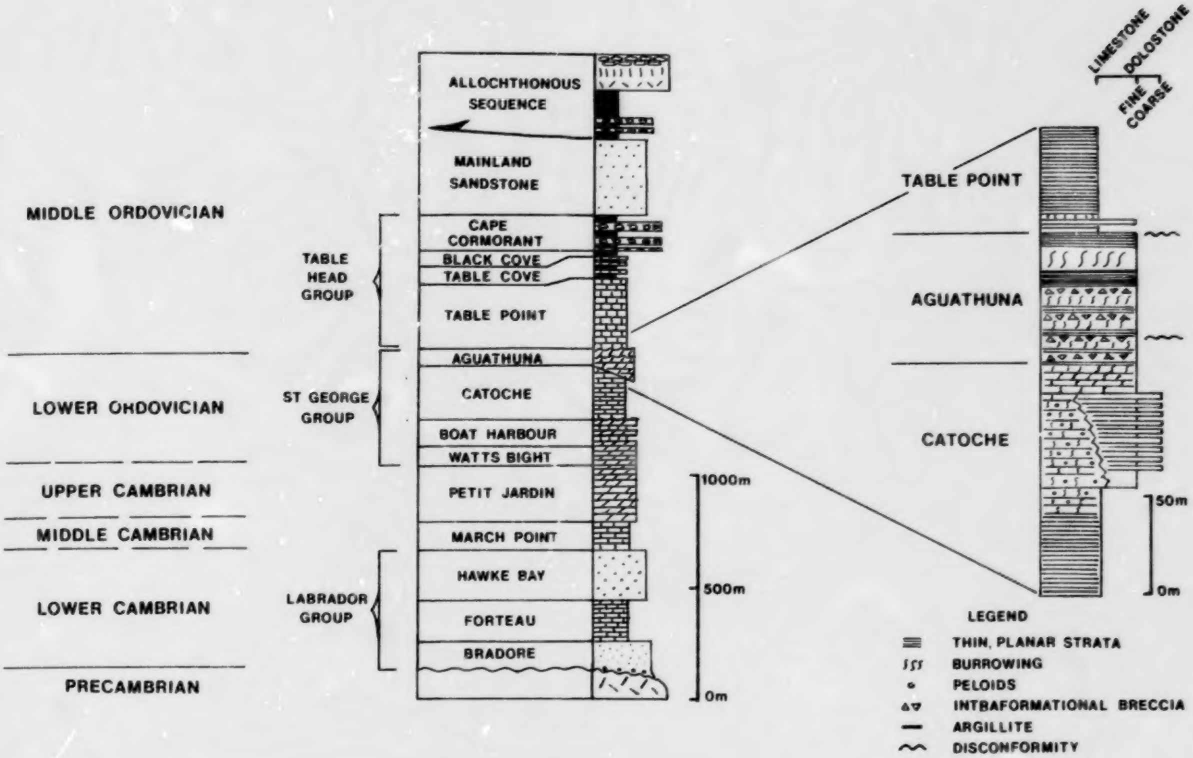
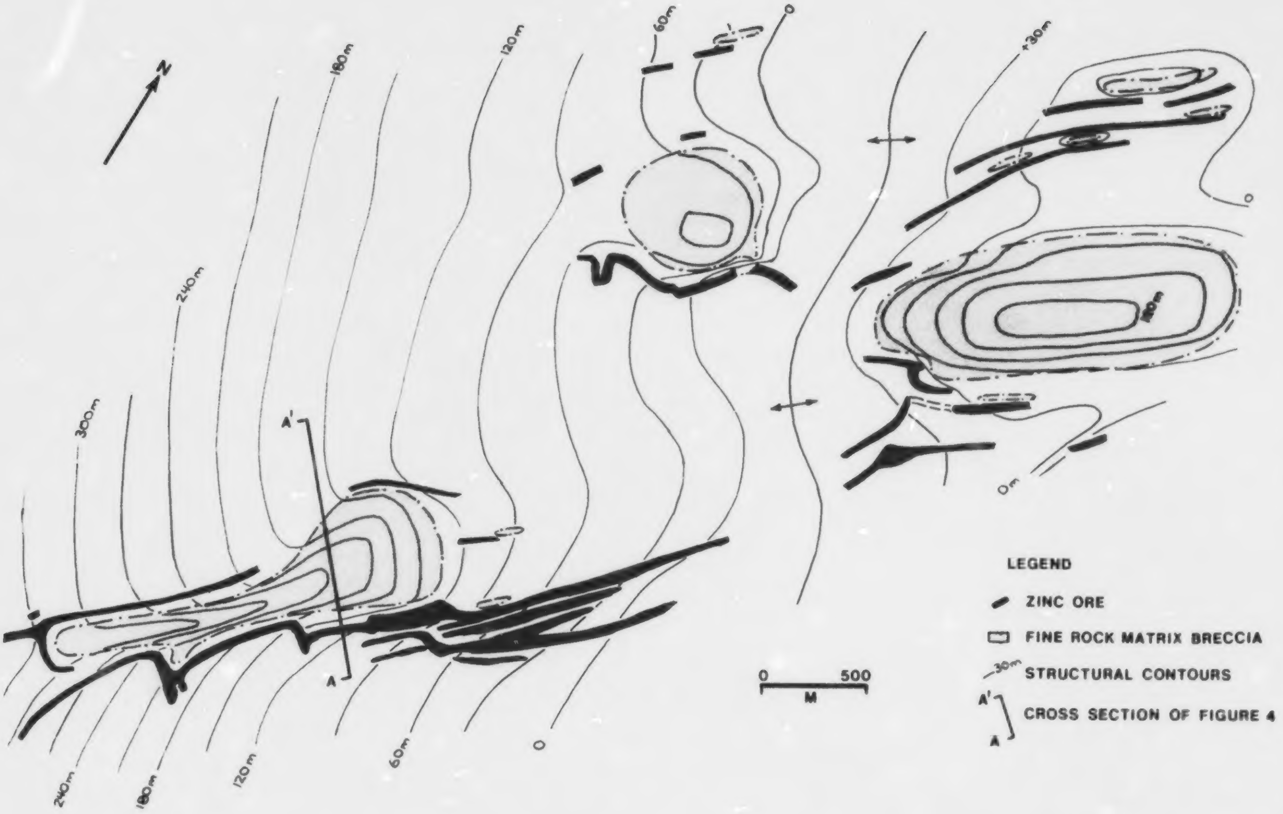

MIDDLE ORDOVICIAN
LOWER ORDOVICIAN
UPPER CAMBRIAN
MIDDLE CAMBRIAN
LOWER CAMBRIAN
PRECAMBRIAN
TABLE HEAD GROUP
ST GEORGE GROUP
LABRADOR GROUP
ALLOCHTHONOUS SEQUENCE
MAINLAND SANDSTONE
CAPE CORMORANT
BLACK COVE
TABLE COVE
TABLE POINT
AGUATHUNA
CATOCHE
BOAT HARBOUR
WATTS BIGHT
PETIT JARDIN
MARCH POINT
HAWKE BAY
FORTEAU
BRADORE
1000m
500m
0m
LIMESTONE
DOLOSTONE
FINE
COARSE
TABLE POINT
AGUATHUNA
CATOCHE
50m
0m
LEGEND
THIN, PLANAR STRATA
BURROWING
PELOIDS
INTRAFORMATIONAL BRECCIA
ARGILLITE
DISCONFORMITY

Figure 2: *Stratigraphy from Newfoundland Zinc Mines set in the stratigraphy of the Humber Zone Autochthon (adapted from James and Stevens, 1982).*

rock matrix breccias (matrix size = 0.01 mm, fragment size = 1 mm to 1 m). Fine rock matrix breccias are restricted to structural depressions in upper St. George Group strata (Figure 3). The other dolostones are developed outside the "breccia-depressions". The overlying upper 16 m of the Catoche Formation and the entire Aguathuna Formation are pervasively dolomitized and contain only minor white dolomite. These dolostones are mostly microcrystalline (0.01 mm) and commonly finely planar laminated (dololaminites). The variety of dolostones of the upper St. George Group is described by Collins and Smith (1975), Coron (1982), and Haywick and James *(this volume)*.

At least 11 ore bodies, averaging 8% zinc, have been defined to date within the white dolostone. Individual ore lenses are long, narrow, and sinuous, 5 to 15 m (rarely up to 30 m) thick, 7 to 70 m wide and 500 to 4000 m long. Their linearity is caused by ore-controlling vein systems which in part border structural depressions oriented 045° to 060° and 180° (Figure 3). Although the veins control the orientation of the ore, most of the sphalerite was deposited in white dolomite strata, peripheral to the veins.

Sphalerite stratigraphy and paragenesis have been used with some success at other Mississippi Valley type deposits (McLimans et al., 1980; Craig et al., 1983). At Daniel's Harbour, as many as four stages of sphalerite precipitation are recognized by color changes in mineralization lining previous cavities. Relative


N
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LEGEND
ZINC ORE
FINE ROCK MATRIX BRECCIA
30m STRUCTURAL CONTOURS
A' A CROSS SECTION OF FIGURE 4

Figure 3: *Newfoundland Zinc Mines. A plan view of the upper Catoche Formation, showing the location of zinc orebodies relative to structural depressions and the distribution of fine rock matrix breccias. Structural contours record the depth of an upper Catoche stratum below a datum plane 100 m above sea level (contour interval = 30 m).*

ages of brecciation can be tested by the presence or absence of these sphalerite stages.

Classification of Breccia Types

Five breccia types are differentiated on the basis of macrotexture, petrography, and geometry (Table 1):

(1) intraformational breccias;

(2) fine rock matrix breccias subdivided into (2a) oligomictic and (2b) polymictic types; and

(3) white spar breccias subdivided into (3a) true spar breccias and (3b) pseudobreccias.

The stratigraphic, compositional and geometric relationships of those breccias are summarized in Table 1 and Figures 4 and 5.

(1) Intraformational Breccias

The intraformational breccias possess a fine rock matrix, but are distinguished by their stratigraphic characteristics. They are extensive horizons specifically

Table 1: *Summary of stratigraphic, compositional and geometrical relationships observed within five breccia rock types at Newfoundland Zinc Mines.*

Type of Breccia		Stratigraphic Position	Composition	Geometry
Intraformational		Aguathuna Formation	Local angular dolostone clasts, chert clasts, nodules, sandy mud matrix, clay residues, clast and matrix support	Laterally extensive, strata-bound
Fine Rock Matrix	Oligomictic	Upper Catoche Formation	Local clasts (1-3 cm diameter), subrounded clasts, sandy mud matrix, matrix support; recrystallized clasts and matrix	Laterally continuous for 30 to 3000 m; localized around structural depressions and fracture zones
	Polymictic	Aquathuna and Upper Catoche Formations	3 or 4 mixed lithologies of clasts (1 cm to 1 m diameter), gravelly-sandy mud matrix, matrix support, clasts fractured, not recrystallized	Vertically crosscuts pre-existing dolostone; limited lateral extent; common around breccia margins
White Spar Breccias	True Breccias	Upper Catoche Formation	Large angular clasts (up to 1 m diameter) includes pseudobreccia; megacrystalline white dolomite matrix	Veins and bodies crosscutting strata; vertical fracture system
	Pseudobreccias	Upper Catoche Formation	Megacrystalline white dolomite replaces 5% to 80% of mottled gray dolomite; partial cavity infilling; minor breccia	Selectively replaces horizontal strata over thousands of metres

related to primary lithofacies. Stouge's (1982) conodont data indicate that these breccias may overlie disconformities.

Lithology - Angular rotated clasts (1 to 5 cm in diameter) derived from local, overlying dololaminites are enveloped by a recrystallized sandy to gravelly mud matrix. Green and black clay residues form part of the matrix and are concentrated at the base of breccias. Mud-filled fractures and mosaics of slightly displaced fragments are present where breccias are poorly developed. Chert occurs as clasts within breccias and horizons of nodules in underlying strata.

Geometry - The breccias are tabular bodies, 30 to 50 cm thick, which can be correlated between drill holes for a distance of at least 10 km.

Stratigraphic Association - The breccias occur in specific lithofacies successions in the Aguathuna Formation. They abruptly overlie burrow-mottled subtidal dolostones and underlie planar laminated supratidal dolostones (Figure 5). Locally, both breccias and underlying dolostones are recrystallized. This sequence is repeated six times in the Aguathuna Formation.

Genesis - The intraformational breccias are interpreted as synsedimentary or early diagenetic in origin. They mark abrupt breaks between subtidal and supratidal environments, which could be interpreted as either disconformities (e.g. Fischer's (1964) loferites or postdepositional dissolution surfaces (e.g. Lucia (1972)).

(2) Fine Rock Matrix Breccias

In contrast to intraformational breccias, fine rock matrix breccias are found within and around the structural depressions and fracture zones. Within these bodies of breccia, two major types can be distinguished based on petrography and geometry: oligomictic and polymictic types.

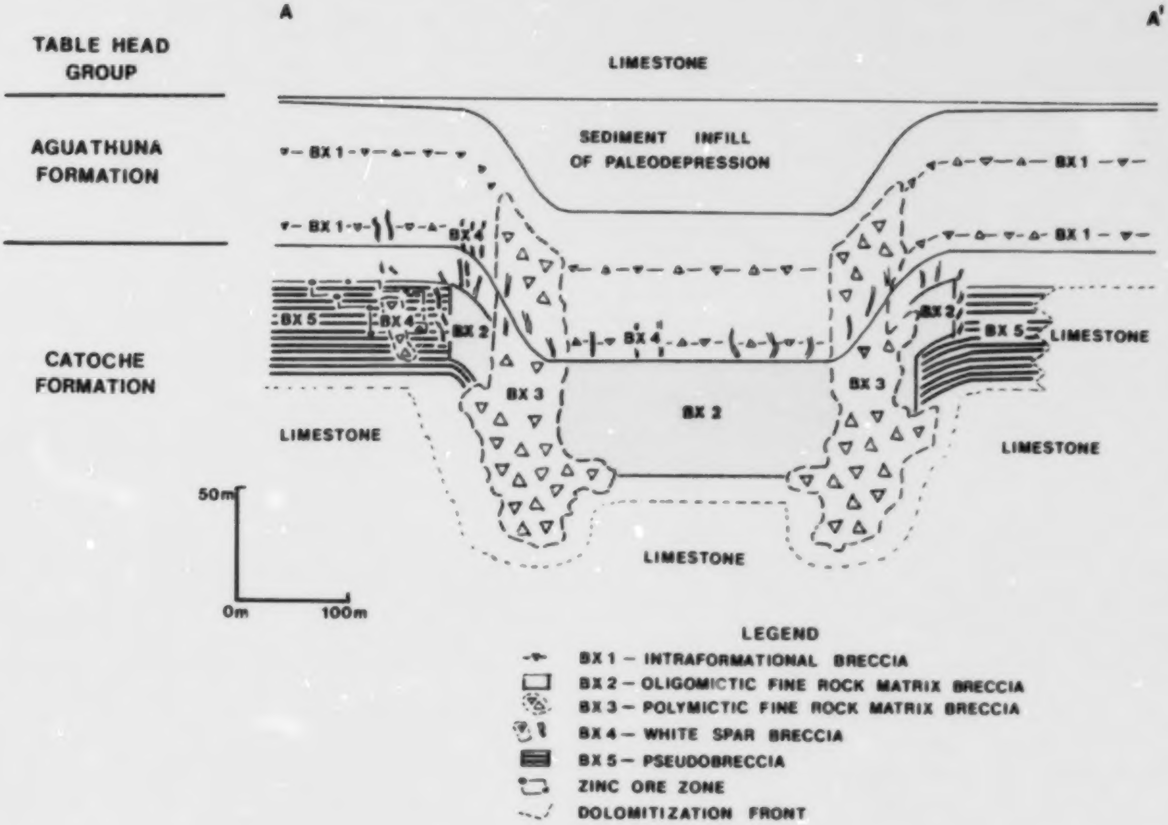

A
A'
TABLE HEAD GROUP
LIMESTONE
AGUATHUNA FORMATION
SEDIMENT INFILL OF PALEODEPRESSION
BX 1
BX 1
BX 4
BX 5
BX 4
BX 2
BX 4
BX 2
BX 5
LIMESTONE
CATOCHE FORMATION
BX 3
BX 3
BX 2
LIMESTONE
LIMESTONE
LIMESTONE
50m
0m
100m
LEGEND
BX 1 – INTRAFORMATIONAL BRECCIA
BX 2 – OLIGOMICTIC FINE ROCK MATRIX BRECCIA
BX 3 – POLYMICTIC FINE ROCK MATRIX BRECCIA
BX 4 – WHITE SPAR BRECCIA
BX 5 – PSEUDOBRECCIA
ZINC ORE ZONE
DOLOMITIZATION FRONT

Figure 4: *Distribution of the five breccia types across an ore zone and a structural depression. Location of the cross-section is indicated on Figure 3.*

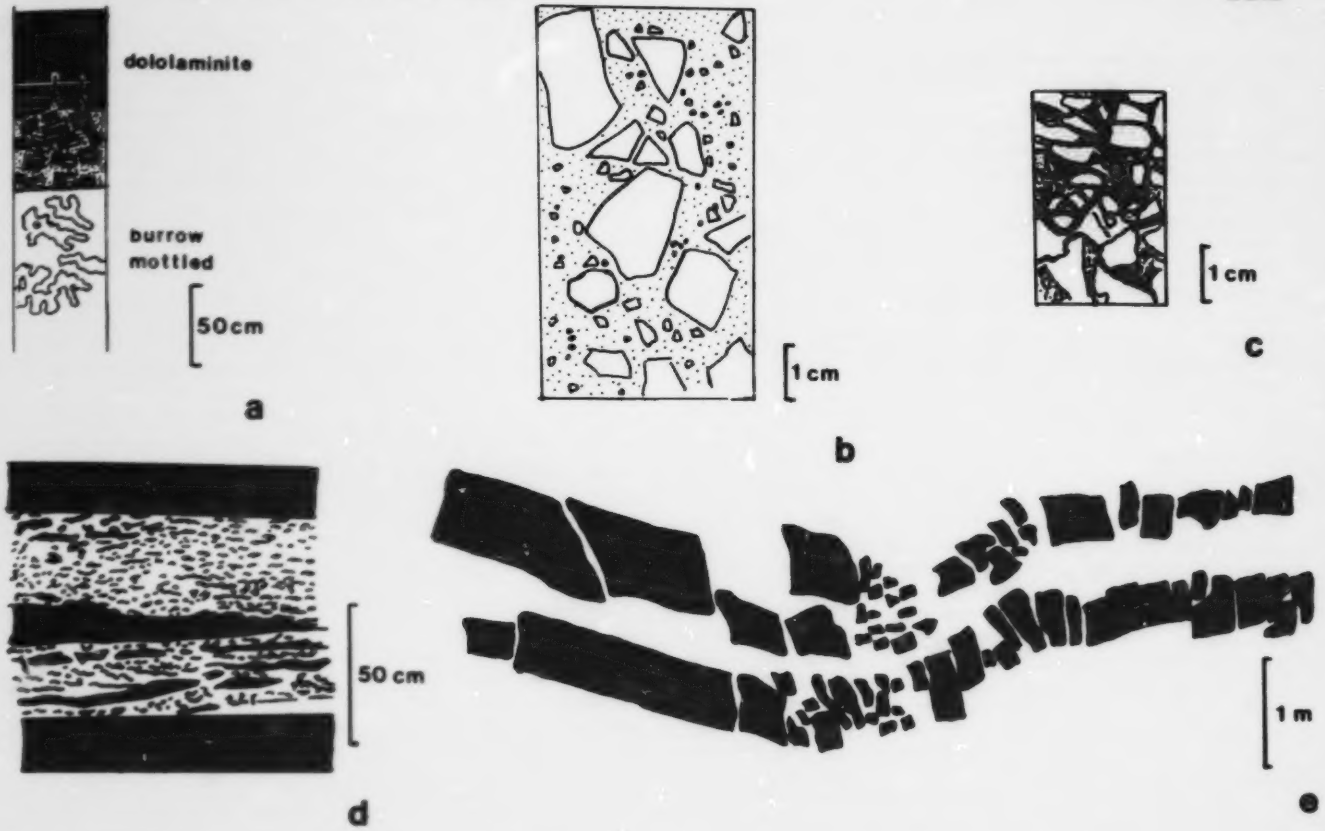
(2a) OLIGOMICTIC BRECCIAS

Lithology - Small fragments (0.1 to 1 cm diameter) consist of one lithology, mottled dolostone, derived from one stratigraphic level. These subrounded to subangular clasts are recrystallized to 0.1 mm dolomite. The rock is only partially matrix-supported, with clasts often bounded and separated by black residue-rich stylolites. The matrix is finely crystalline (0.01 mm), fairly homogeneous and rich in black residues (Figure 5). The residues were identified by Collins (1971) as iron oxides.

Geometry - These breccias are stratigraphically controlled and can be correlated within and slightly beyond the boundaries of the structural depressions, laterally continuous up to 200 by 1000 m (Figure 3). As well, some small, 10 m wide, oligomictic breccia bodies occur in association with fracture zones.

Stratigraphic Association - The oligomictic breccias are restricted to the upper Catoche Formation, constituting 60% to 90% of the section. Overlying strata are intact and characterized by common veins of gray and white dolostone.

Genesis - The upper Catoche Formation underwent local dissolution and dolomitization during the formation of the structural depressions, prior to the deposition of the Table Head Group and the later sphalerite emplacement. Dissolution resulted in the collapse of strata and the production of breccias, and, in part, the



a. Intraformational breccias relative to dololaminite and burrow mottled lithofacies. Clay residues at the base of the breccia.

b. Polymictic fine matrix breccia, with fragments "floating" in matrix.

c. Oligomictic fine rock matrix breccia with fragments compacted and black residue in matrix and between clasts.

d. Pseudobreccia with horizontal fabric, between grey dolomite strata.

e. Grey dolomite strata broken by subsidence and faulting to form a true spar breccia.

***Figure** 5. Aspects of breccia macrotextures.*

formation of the major structural depressions; fractures which propagated through overlying strata were later filled with veins. The porous breccias provided permeability for dolomitizing fluids, which produced the pervasive recrystallization.

(2b) POLYMICTIC BRECCIAS

Lithology - Clasts of up to four lithologies are intermixed, the most distinctive of which are light gray laminated clasts characteristic of the Aguathuna Formation. The clasts range in size from 1 m to 1 cm. The angular, commonly fractured clasts float in 40% to 70% poorly sorted matrix comprising 1 to 5 mm clasts and 0.1 mm euhedral dolomite crystals enveloped in black residues (Figure 5).

Geometry - These breccias crosscut the stratigraphy. One unit was observed to be 10 m wide with vertical boundaries. Information from other areas indicates irregular widening at specific stratigraphic levels.

Stratigraphic Association - The breccias tend to be localized around the margins of the structural depressions and crosscut the stratigraphy of the Aguathuna Formation through the upper 60 m of the Catoche Formation. Clasts of the Aguathuna Formation have been displaced up to 60 m below their original stratigraphic position.

Genesis - The origin of the polymictic breccias is directly related to structural changes at the margins of depressions.

Dilation at the rims caused by collapse or downfaulting created enough space for rock debris to fall as much as 60 m. The openings may have also been enlarged by dissolution, forming significant cavities that were subsequently filled with breccia.

(3) White Spar Breccias

Megacrystalline white dolomite is extensive in the vicinity of the ore zones; however, it is not present in areas containing matrix breccias. The white dolomite is considered to be younger than the fine rock matrix breccia which it locally replaced. Much of the white dolomite was precipitated at the same time as the sphalerite.

In this classification, distinction is made between true spar breccias and pseudobreccias. A true spar breccia contains displaced and rotated gray dolomite fragments surrounded by a matrix of megacrystalline white dolomite. The gray dolomite patches of pseudobreccia often appear to be surrounded by megacrystalline white dolomite. The gray dolomite patches of pseudobreccia often appear to be surrounded by megacrystalline white dolomite; however, they are *in situ* and interconnected in three dimensions (Figure 5). The white dolomite of pseudobreccia is either open-space-fill or a recrystallization fabric. Since true spar breccias and pseudobreccias are overprinted in places, the distinction is not always clear.

(3a) TRUE SPAR BRECCIAS

Lithology - Angular fragments of gray dolomite and pseudobreccia, up to one metre in diameter, are supported by a matrix of megacrystalline white dolomite. These fragments have often only slightly rotated from their original position. A few spar breccias were originally fine rock breccia. In these cases, white spar has selectively replaced gray dolomite matrix.

Geometry - Three types of spar breccia are delineated: (1) veins in gray dolomite strata between pseudobreccia; (2) local breccias within pseudobrecica beds; and (3) linear bodies which crosscut the stratigraphy (10 to 30 m wide and 100 m or more long). Linear breccias are usually a collection of subvertical veins.

Stratigraphic Association - These breccias are restricted to the Upper Catoche Formation. Their occurrence is controlled by vein density, faulting and subsidence of strata.

Genesis - Spar breccias formed where strata were ruptured by faulting and/or dissolution. Large fragments of these strata were slightly displaced and rotated. Some of these breccias were cogenetic with pseudobreccias; however, the larger linear bodies are late structures, associated with vertical movements, and formed after most pseudobreccia development. Only late stage sphalerite occurs in these dolomites.

(3b) PSEUDOBRECCIA

Lithology - Megacrystalline white dolomite constitutes 5% to 80% of strata 0.3 to 1 m thick. The remainder of the rock consists of dispersed irregular patches of medium crystalline gray dolomite with an internal relict mottled fabric. Intercrystal and vug porosity is abundant. White and gray dolomite alternate in a horizontal, variably developed, 'banded' fabric (Figure 5). Breccia fragments of gray dolomite occur locally in veins and cavity fills.

Geometry - Pseudobreccia strata and intercalated gray dolostones are selectively developed according to textural variation in the original limestones. As a result, it is possible to correlate specific strata over distances greater than 15 km. The highest percentages of white dolomite are concentrated around vein systems, but pseudobreccia development in strata extends laterally over thousands of metres.

Stratigraphic Association - Pseudobreccia development is limited to strata 16 to 50 m below the top of the Catoche Formation. The position coincides with the upper limit of limestones and the occurrence of cyclic, mottled, peloidal mudstones and wackestones. In this interval, pseudobreccia is excluded from areas of the older fine rock matrix breccia.

Genesis - Pseudobreccia formed by diffusion of dolomitizing fluids into peloidal limestone strata to a depth of 50 m below the top of the Catoche Formation. Linear vein systems were the loci of fluid movement, the area of best spar development, and ore conduits. White dolomite crystallized by selective replacement around early dolomites (Haywick and James, *this volume*) and filling of vugs and cavities. Sphalerite was deposited prior to and during white dolomite formation.

Conclusions

Five breccia types occur in association with sphalerite deposits at Daniel's Harbour, Newfoundland. Differentiation of breccia styles is essential to an understanding of the permeability, porosity evolution, and subsequent sphalerite deposition. Subaerial exposure of the carbonate platform is suggested by intraformational breccias. Fine rock matrix breccias formed by dissolution and collapse beneath this exposed platform. Early structural dilation along the margins of large depressions (200 m by 1000 m) resulted in the formation of polymictic breccias. Subsequent deformation produced open space fracture systems which became filled by sphalerite and megacrystalline white dolomite. Peloidal limestone strata were altered to pseudobreccia outward from vein systems. Most sphalerite was precipitated in pseudobreccia strata adjacent to veins. Linear spar breccias formed as a result of vertical tectonic movements during the latest stages of mineralization.

Acknowledgements

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GEOLOGY AND MINERAL DEPOSITS OF THE LUSHS BIGHT GROUP, NOTRE DAME BAY, NEWFOUNDLAND

by

B.F. Kean
Mineral Deposits Section

Abstract

Geological mapping in the Lushs Bight Group has shown that the Group is divisible into a number of fault-bounded blocks. Within these blocks, the group can locally be subdivided into different stratigraphic and/or lithological units. The major stratigraphic subdivisions are sheeted dikes and mafic pillow lava.

The stratigraphic top of the Lushs Bight Group is marked locally by hematization and the occurrence of interpillow jasper and jasper lenses with common magnetite. This is overlain by a distinctive unit of chocolate brown argillite and minor interbedded red chert.

The Lushs Bight Group is involved in regionally developed, northeast trending folds with an associated axial planar foliation. These structures are folded around open folds, flexures and kinks with a north striking axial plane.

Sulfide mineralization in the Lushs Bight Group is syngenetic and occurs as disseminations and stringers and as massive sulfides. It occurs at different stratigraphic levels and in different lithologies. The mineralization is discussed under four major headings: (1) in the sheeted dikes, (2) near the sheeted dike - pillow lava interface, (3) within pillow lava and intercalated pyroclastics at an assumed higher stratigraphic level, and (4) in sediments at the top of the Lushs Bight Group.

Introduction

This report summarizes the results of the second field season of a project designed to investigate the regional geology and mineral deposits of the Lushs Bight Group. The reader is referred to Kean (1983) for a summary of the results of the first year. The objectives of this project are to establish a stratigraphic and structural framework for the Lushs Bight Group, to study the deposits in the area, to evaluate their economic significance, and to develop a model that will be useful in the search for economic mineral deposits.

Access to the area is from the Trans Canada Highway via the Springdale, King's Point, Little Bay and Robert's Arm roads, and via boat from any of the coastal communities. Bedrock exposure along the coast is excellent and nearly continuous; elsewhere, it is good to poor.

Much of the area was extensively mapped and explored by BRINEX during the 1960's and early 1970's. Several thesis studies (e.g. Donohoe, 1968; Fleming, 1970; Marten, 1971a; DeGrace, 1971; West, 1972; Kean, 1973; O'Brien, 1975) supported by BRINEX have been done on the area and these add to a voluminous data base. Espenshade (1937), MacLean (1947), Neale et al. (1960) and Williams (1962) produced regional maps of the area, and Dean and Strong (1975) compiled the geology of the area on a scale of 1:63,360.

Despite this large amount of earlier work, the Lushs Bight Group has generally been mapped as an undivided sequence of pillow lava, chlorite schist and basic intrusive rocks. Consequently, the main objective of this project has been to elucidate the stratigraphy and structure of the Lushs Bight Group and to establish whether the stratigraphy and/or structure has any control on mineralization in the group.

The main findings of the 1983 field season are the following:

(1) A distinctive unit of chocolate brown argillite and common jasper marks the stratigraphic top of the Lushs Bight Group.

(2) Banded pyrite, pyrrhotite and magnetite are commonly interbedded with these sediments.

Contribution to the Canada-Newfoundland co-operative minerals program 1982-84. Project funded by the Newfoundland Department of Mines and Energy.

(3) Rocks assigned to the Lushs Bight Group on Pilley's and Triton Islands are lithologically different from the Lushs Bight Group elsewhere and are, therefore, removed from that group.

(4) The volcanic rocks of the Lushs Bight Group are locally subdivisible into different lithological units.

(5) Sheeted dikes are widespread in the Lushs Bight Group; several new areas of dikes were discovered.

(6) The sequences on Pilley's and Triton Islands display monoclinal folding.

(7) Highly variolitic and quartz amygdaloidal pillow lavas are generally associated with mineralization.

(8) Sulfide mineralization occurs in chlorite schist derived from pillow lava and/or intercalated tuff.

(9) Most sulfide mineralization occurs as disseminations and stringers; banded or bedded sulfides occur in a few showings.

Regional Geology

The regional geology of the Springdale Peninsula was previously described by a number of workers, including MacLean (1947), Williams (1962) and Peters (1967). The area is also included in a 1:250,000 scale geological compilation of the Newfoundland Central Volcanic Belt (Kean, 1977). Dean (1978) summarized the regional geology of Notre Dame Bay, including the map area. The following discussion is adapted from Kean (1983).

The Lushs Bight Group occurs in western Notre Dame Bay, north of the Lobster Cove Fault. It outcrops between Southwest Arm in the west and Badger Bay in the east. It is faulted against the Silurian-Devonian Springdale Group and the Ordovician-(?)Silurian Roberts Arm Group along the Lobster Cove Fault to the south. Local outliers of the Springdale Group occur within the Lushs Bight Group north of the Lobster Cove Fault. These rocks are generally fault-bounded; however, an unconformity may exist on the Lushs Bight Group in the Davis Pond area (McGonigal, 1970). The Lushs Bight Group is conformably overlain by the Lower Ordovician Western Arm Group and, presumably, by the Lower Ordovician Catchers Pond Group to the north and west. It is faulted against the Cutwell Group on the northeast coast of Sunday Cove Island. This fault is presumed to continue underwater between Long Island and Pilley's Island and to juxtapose these groups in that area.

The Lushs Bight Group is considered to be of ophiolite affinity. However, as defined by Espenshade (1937) and used by MacLean (1947), it also included sedimentary and volcanic rocks now considered to be of island arc affinity. These rocks were subsequently assigned to the Western Arm Group (Marten, 1971a,b) and the Cutwell Group (Kean, 1973, 1983). Thus, the group now includes only mafic pillow lava, breccia and agglomerate, sheeted diabase dikes, gabbro dikes and sills and small bodies of ultramafic rock of ophiolite type. These rocks are low potash tholeiites with chemical similarities to modern oceanic crust (Papezik and Fleming, 1967; Smitheringale, 1972; Strong, 1973).

The Lushs Bight Group is folded into major northeast trending folds with the limbs displaced or cut off by northeast trending wrench faults. Later deformation resulted in folding about a north-south axis, resulting in southeast strikes.

The Lushs Bight Group is intruded by various bodies of probable Ordovician age, including the Colchester Pluton, the Cooper Cove Pluton and many small stocks and plugs interpreted to be contemporaneous with volcanism. It is also interpreted to be intruded by the Brighton Gabbro Complex, which gives an $^{40}Ar/^{39}Ar$ radiometric age of 495 ± 5 Ma (Stukas and Reynolds, 1974). A Late Cambrian age is thus suggested for most of the group.

MacLean (1947) reported a single Lower Ordovician brachiopod, *Discotreta* sp., from the lowermost part of the conformably overlying Western Arm Group.

The Lushs Bight Group and overlying volcanic sequences are correlative on the basis of age and stratigraphy with the Snooks Arm Group, which includes the Betts Cove ophiolite. The two sequences are interpereted to lie on opposing limbs of a major syncline.

Lushs Bight Group

General Statement

Geological mapping conducted during this project has shown that the Lushs Bight Group is divisible into a number of fault-bounded blocks (Figure 1). Within these blocks, the group can be subdivided into

L E G E N D

Carboniferous

14 Reddish brown to greyish red conglomerate and sandstone; grey shale and siltstone and minor limestone.

Silurian to Devonian

SPRINGDALE GROUP (Unit 13)

13 Red and brown conglomerate, sandstone and siltstone; minor volcanic rocks.

12 Pink to red granite, granodiorite and quartz-feldspar porphyry.

Ordovician or Silurian

ROBERTS ARM GROUP (Unit 11)

11 Undivided mafic and felsic volcanic rocks.

Lower to Middle Ordovician

10 10A, Colchester Pluton: medium grained diorite, quartz diorite and minor granodiorite. 10B, Coopers Cove Pluton: fine to coarse grained diorite, granodiorite and granite, common diabase. 10C, Wellmans Cove Pluton: medium grained diorite and quartz diorite with mafic and ultramafic inclusions. 10D, Bob Head Pluton: medium to coarse grained diorite, gabbro and quartz monzonite.

WESTERN ARM/CUTWELL GROUPS (Unit 8)

8 Massive and pillow basalt and andesite, locally feldsparphyric. Lithic and pyroxene crystal-lithic tuff, lapilli tuff, breccia and agglomerate. Epiclastic and sedimentary rocks.

9 Highly vesicular pillow basalt and feldsparphyric andesite. Lithic and pyroxene crystal-lithic tuff, lapilli tuff and breccia. Interbedded red and green argillite and tuff.

CATCHERS POND GROUP (Unit 7)

7 Silicic lava, agglomerate and tuff; massive basalt, pillow lava and agglomerate; thin beds of fossiliferous limestone and limestone conglomerate.

Lower Ordovician and Earlier

LUSHS BIGHT GROUP (Units 1-6)

6 Brighton Gabbro: medium to coarse grained, hornblende clinopyroxenite, hornblendite, gabbro, diorite and quartz diorite.

5 Black, locally hematitized, pillow lava with common interpillow and lenses of jasper. Overlain by thinly bedded, chocolate-brown argillite and interbedded red chert.

4 Thinly bedded, grey green and black, mafic tuff and volcanic sediment; minor red argillite and chert. Magnetite lenses and magnetite rich tuff locally present.

3A Fine grained to aphanitic, gray to green, epidotized, pillow lava with common diabase and gabbro dikes.

3B Fine grained to aphanitic gray to green, commonly epidotized pillow lava with extensive pillow breccia and isolated pillows in places. Intercalated mafic tuff, locally extensive.

3C Fine grained to aphanitic, gray to green, commonly epidotized pillow lava and extensive chlorite schist; highly variolitic and quartz amygdaloidal in places. Mafic agglomerate, breccia and tuff; minor dacitic rocks. Extensive diabase dikes in places and locally sheeted.

2A Fine grained to aphanitic, gray-green to green, epidotized pillow lava with extensive diabase and gabbro dikes. Minor agglomerate and breccia. Chlorite schist extensive in places.

2B Undivided sheeted dikes and pillow lava with extensive dikes; locally variolitic. Minor mafic agglomerate, breccia and tuff. Minor dacitic rocks.

1 Sheeted diabase dikes; locally with gabbro and pillow lava screens.

▨ Variolitic and quartz amygdaloidal pillow lava

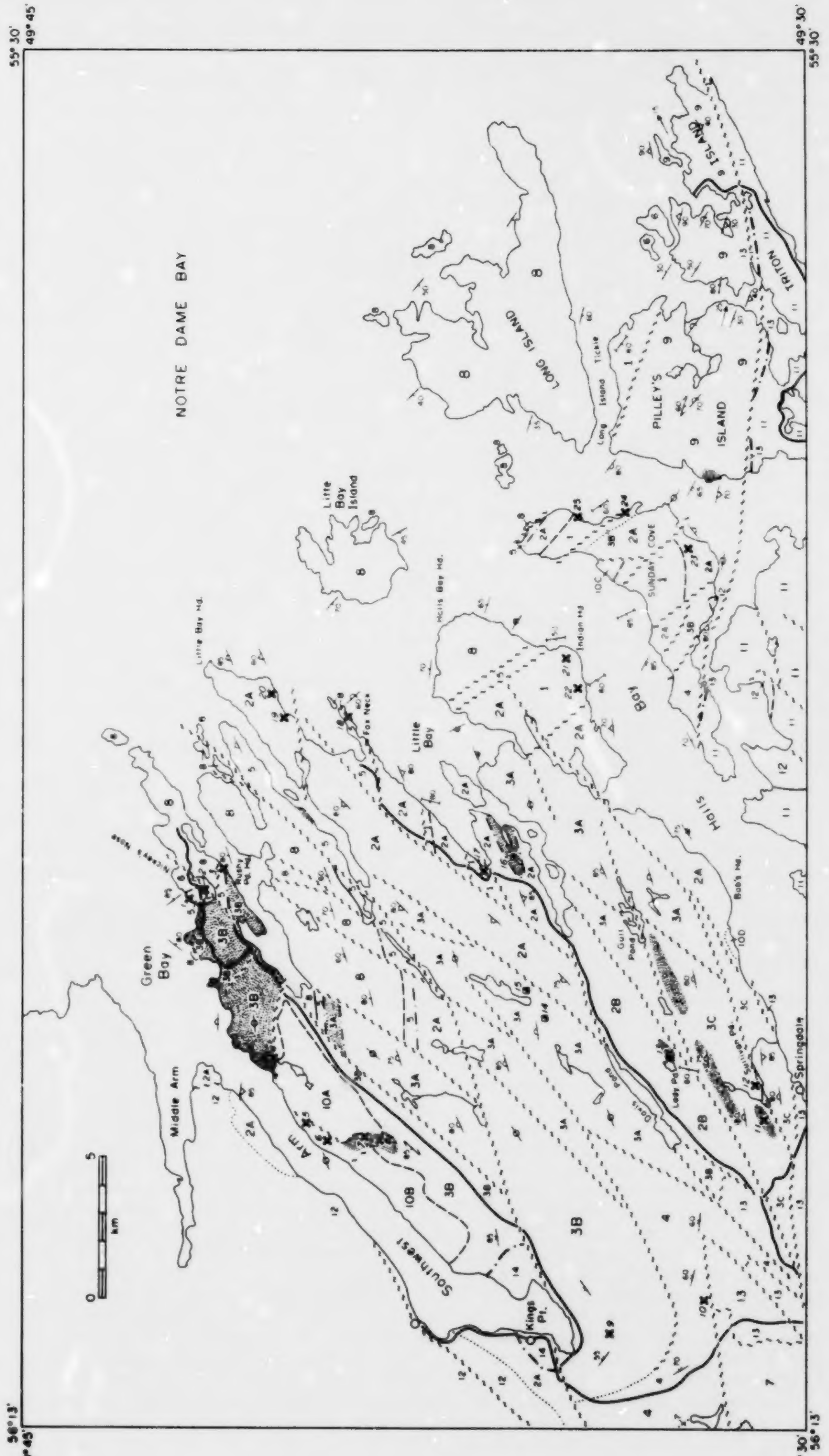
49°45'
55°30'
49°30'
55°30'
49°45'
56°13'
49°30'
56°13'
NOTRE DAME BAY
LONG ISLAND
Long Island Tickle
PILLEY'S ISLAND
TRITON ISLAND
Little Bay Island
Little Bay Hd.
Hall's Bay Hd.
Little Bay
Fox Neck
Indian Hd.
SUNDAY COVE
Halls Bay
Bob's Hd.
Green Bay
Rushy Pd. Hd.
Middle Arm
Southwest Arm
Kings Pt.
Gull Pond
Davis Pond
Springdale
0
5
km

Figure 1: Simplified geological map of the Lushs Bight Group, Notre Dame Bay, Newfoundland.

different stratigraphic units and/or different lithological units. The major subdivisions are sheeted dikes (Unit 1) and mafic volcanics (Units 2 to 5). The most common rock type is fine grained to aphanitic, gray-green and green pillow basalt. The volcanic rocks, locally, can be subdivided into different stratigraphic and/or lithologic units. Pillow lava with extensive diabase dikes and dikes with pillow screens constitute Unit 2A. Unseparated areas of sheeted diabase dikes and pillow lava with diabase dikes are included in 2B.

The stratigraphic position of Unit 3 is not clear; it may in part be equivalent to Unit 2. It is lithologically subdivided on the basis of the presence of extensive pillow lava with common diabase and gabbro dikes (Unit 3A), extensive pillow breccias (Unit 3B), and/or extensive intercalated mafic tuff (Unit 3C). Unit 4 consists mainly of mafic tuff, agglomerate and volcaniclastic sediments with intercalated pillow lava.

The mafic volcanics (Unit 5) at the top of the Lushs Bight Group are generally black rather than the usual green color, are often hematized and contain common interpillow jasper, jasper lenses and locally magnetite lenses. The mafic volcanics are overlain by a distinctive unit of thinly bedded, chocolate brown argillite and red chert. These sediments are in turn overlain by green-gray and yellow-green tuff, argillite and pyroxene crystal tuffs (see also Kean, 1983).

Areas with extensive variolites and quartz amygdules are shaded on the map.

The sequence north of the Lobster Cove Fault on Pilley's and Triton Islands consists of pyroclastic rocks with intercalated vesicular pillow lava (Unit 9), and is lithologically different from the main portion of the Lushs Bight Group. This sequence is lithologically and stratigraphically similar to the rocks of the Cutwell and Western Arm Groups (Unit 8).

The rocks of the map area have been folded about northeast trending axes. These early or first phase(?) structures have been openly folded or kinked about north trending axes, resulting in southeast strikes. North facing monoclinal folding is developed in the sequences on Pilley's and Triton Islands. Major northeast trending faults cut the major fold structures.

The present large area of exposure is a result of structural repetitions, the true thickness of the Lushs Bight Group is probably between 3 and 4 km.

Lithologies of the Lushs Bight Group

Unit 1 - Sheeted Dikes

Sheeted diabase dikes occur in the Little Bay and Indian Head areas, along the west side and at Paddox Bight on the east side of Sunday Cove Island, and along the north coast of Pilley's Island. Areas entirely underlain by dikes also occur north of St. Patricks in the Lady Pond area, and east of the Little Bay road.

The dikes trend slightly east of north with slight variation, and dip to the west. Pillow and gabbro screens are locally present.

The sheeted dikes average 0.5 m thick and vary from less than 0.25 m to 2 m thick. The sheeted dikes consist predominantly of diabase with common gabbroic dikes and rare dikelets of aphanitic diabase (basalt) less than 2 cm in width. The diabase dikes are fine to medium grained, green and equigranular.

The gabbro dikes are medium grained, equigranular and locally porphyritic. Dikes completely replaced by epidote are locally present. The dikes generally display chilling on one margin, but locally both margins are chilled against gabbro screens and larger gabbro dikes. The dikes generally grade into areas of dikes with pillow screens and, in the Little Bay area, into pillow lava with extensive dikes. Dikes along the west shore of Sunday Cove Island, in particular the northern unit, are highly schistose and are often chlorite schist. Variolites are locally developed in the dikes.

The sheeted dike zones commonly develop rusty weathering scree slopes because of the abundant disseminated pyrite in them.

Unit 2 - Pillow Lava and Diabase Dikes

In places, this unit can be demonstrated to directly overlie the sheeted dike unit with a gradational contact. The unit then varies from dominantly sheeted dikes with pillow lava screens at its base to pillow lavas with extensive to common dikes at higher stratigraphic levels. These rocks are assigned to Unit 2A.

Extensive dikes in pillow lava characterize the Little Bay Head and north side of Little Bay areas. In the Little Bay Head area, there are sections more than 50 m thick that consist of multiple intrusions of medium grained gabbro and diabase dikes which are individually as wide as 2 m. Locally, these extensive dike sections are sheeted, i.e. they possess one chilled margin. The dikes strike slightly east of north at a high angle to the enclosing pillow lava.

The area between Lady Pond and the Little Bay road consists of pillow lava and associated tuff with common to extensive diabase dikes and extensive areas of sheeted dikes. These rocks are unseparated on the accompanying map and are indicated as Unit 2B. Fine grained to aphanitic, cleaved, green dacitic tuff also constitutes a minor portion of this subunit.

The pillow lavas in Unit 2 are fine grained to aphanitic, green to gray-green and equigranular. They are variably epidotized, commonly with their cores completely replaced by epidote and enveloped by chlorite schist. There are local areas where chloritic alteration predominates, in particular in shear zones. Quartz and calcite veining is common. The pillows are characterized by thin rims and are generally nonvesicular. They are closely packed, and interpillow material is minor, although locally white, gray, green and red interpillow chert is present, in particular, near the Little Bay and Sleepy Hollow mines. Interpillow aquagene tuff is rare. Minor breccia, pillow breccia and agglomerate occur intercalated with the pillow lava. The pillows vary in size from 15 cm to 1 m and in shape from round to elliptical. They are commonly flattened and moderately elongated in the plane of deformation. In the shear zones, the pillow lavas become chlorite schist, often enveloping epidote knots. Quartz, calcite and epidote veins are common. Quartz veining is locally extensive.

Whitish green, leached and silicified pillow lava and minor breccia occur on the coast along strike from the Little Bay and Sleepy Hollow mines.

Rocks constituting Unit 2B consist of sheeted dikes similar to Unit 1 and pillow lavas and dikes similar to Unit 2A. Chlorite schist is common as is mafic tuff, agglomerate and breccia. Fine grained green dacitic (field term based on estimated SiO_2 content) tuff is locally present, particularly near the Lady Pond prospect. Magnetite chert and rare magnetite lenses are also present in this area.

Varioles and quartz amygdules are extensive in the pillow lavas in places, particularly in areas of sulfide mineralization. The variolites are altered to epidote and disseminated throughout the pillows but are locally concentrated either in the cores or near the rims of the pillows. In places, they are up to 1 cm across.

The related dikes are fine to medium grained, green, equigranular diabase and gabbro. Epidote veins and patches are scattered throughout. The dikes vary from a few centimetres to about 2 m wide. They are commonly highly pyritic. The dikes are generally boudinaged in the shear zones.

Unit 3 - Pillow Lava, Pillow Breccia and Tuff

Unit 3 is subdivided into a sequence of dominantly pillow lava with common diabase and gabbro dikes (Unit 3A), a sequence of pillow lava, isolated pillows and pillow breccia and tuff (Unit 3B), and a sequence of pillow lava with intercalated tuff and common chlorite schist (Unit 3C). The exact stratigraphic position of Unit 3 is not clear.

Unit 3A does not differ substantially from Unit 2A and the distinction is arbitrary in many places. The unit is probably in part equivalent to Unit 2A. There generally appear to be fewer dikes of diabase and gabbro (see also Fleming, 1970); however, in the St. Patricks area, massive flows and large gabbro dikes and sills are common. The unit generally grades into the "black facies" of Marten (1971a,b) and minor red chert is locally present.

The pillow lavas are gray to green, fine grained to aphanitic and locally medium grained. They are generally epidotized, with the epidote occurring as veins, veinlets, patches and commonly completely replacing the pillow cores. The pillows vary in size from 15 cm to 1 m across and are closely packed. Small interpillow pillows and pillow fragments are common. Gray and whitish green chert is locally common, in particular northeast of the Whalesback mine. The pillows are generally nonvesicular, nonamygdaloidal and nonvariolitic. Minor variolitic variations occur over the Whalesback mine and locally along the north side of Little Bay.

In the St. Patricks area, fine to medium grained, green, equigranular mafic flows with poorly developed pillow structures are intercalated with the pillow lava. Numerous gabbro dikes and sills 1 to 40 m wide are common. These rocks consist of saussuritized yellow-green feldspar and a chloritized mafic mineral. Locally vesicular and scoriaceous zones are developed. Fine grained diabase dikes intrude these rocks. Feldspar porphyritic dikes are locally present.

The associated gabbro and diabase dikes and sills are fine to medium grained, green and equigranular. Minor feldspar-phyric phases are present.

Porphyritic dikes are locally common in this unit, in particular in the Whalesback - Little Deer mines area. They can be classified into four types containing phenocrysts of feldspar, amphibole and feldspar, and pyroxene in a green, aphanitic matrix. The dikes vary in width from several centimetres to several metres and trend generally either northwest or slightly east of north.

The pillow lava sequence (Unit 3B) exposed south of King's Point and along Southwest Arm is characterized by extensive pillow breccia and isolated pillow units and thin units of finely bedded mafic tuff and minor agglomerate. Altered and silicified pyroclastic breccia is present in the McNeily propect area (#8 on map). The sequence along Southwest Arm is characteristically highly variolitic. Numerous diabase and gabbro dikes intrude the sequence.

Mafic volcanics of Unit 3C consist of pillow lava, locally variolitic and rich in quartz amygdules, or vesicular chlorite schist and locally sheeted diabase dikes. The pillow lavas are aphanitic to fine grained, green, closely packed and commonly have associated breccia and tuff. Rare jasper is present. Within this unit there are extensive areas of fine grained, highly cleaved, green mafic volcanics and/or chlorite schist. In places, bedding is obvious and the rock is probably tuff. In other areas, in particular north of Springdale, it is hard to determine the protolith. Green dacitic tuff is locally present, in particular in the area west of the Sterling prospect (#11 on map).

Diabase and gabbro dikes are common in this unit. Aphanitic, green, felsic dikes are also locally common.

Unit 4 - Tuffs and Pillow Lava

Bedded mafic tuffs predominate in Unit 4. They are gray, green and black in color and fine grained. Black and red argillite beds are locally interbedded with the tuffs. Red chert lenses are locally present. Gray magnetite-rich cherts and magnetite lenses are present in places, in particular in the area south of King's Point. Gray, aphanitic to fine grained pillow lavas are intercalated with these rocks.

Graded bedding and crosslamination are locally developed, and the unit appears to interdigitate with pillow lavas of Unit 3A to the east. The contact with Unit 3B is interpreted to be a fault; however, the unit is also considered to be at a higher stratigraphic level.

Unit 4 on Sunday Cove Island consists of red and green argillite, green sandstone and mafic tuff. Thin pillow lava units are intercalated with the sediments.

Rocks of this unit resemble the sequence overlying the Lushs Bight Group and should perhaps be considered a part of it.

Unit 5 - Pillow Lava and Argillite

The top part of the Lushs Bight Group is characterized by black, fresh or chloritic, commonly hematized, pillow lava with common to extensive jasper lenses and interpillow jasper. These features are irregularly developed in the upper part of the group; although they indicate the top of the group, they are not restricted to a stratigraphic unit. Immediately overlying this sequence, there is a distinctive sequence of chocolate brown argillite and minor interbedded red chert of about 50 m thickness. Pyrite-, pyrrhotite- and magnetite-rich black argillite is commonly interbedded with this sequence, in particular near the top of the sequence. Pyroxene crystal - lithic tuff and well bedded green, gray and yellowish sediments and tuff overlie the chocolate brown argillite and are assigned to overlying volcanic sequences.

Overlying Volcanic and Sedimentary Sequences (Units 7, 8, 9, 11, 13 and 14)

The Lushs Bight Group is directly overlain by pyroclastic and extrusive volcanic rocks of the Catchers Pond (Unit 7) and Western Arm / Cutwell Groups (Unit 8). These rocks were thoroughly described by Marten (1971a,b) and Kean (1973) and will not be discussed here. However, many of the rocks underlying Pilley's and Triton Islands and previously assigned to the Lushs Bight Group are herein considered to be part of the overlying volcanic sequences. This unit (Unit 9) is as yet unnamed. It consists of large, bulbous and highly vesicular, black pillow basalt and lesser amounts of feldspar-phyric green pillow andesite. The lower pillow basalts of the unit contain extensive interpillow red chert and breccias rich in red chert. Sequences of intermediate composition, green breccia, lapilli tuff, and tuff grading upwards into well bedded green and red argillite are interbedded with the pillow lavas.

The Roberts Arm Group (Unit 11) is in fault contact with the Lushs Bight Group. The Springdale Group (Unit 13) and the Carboniferous sedimentary rocks (Unit 14) unconformably overlie the Lushs Bight Group.

Intrusive Rocks

Unit 6 - Brighton Gabbro

A small patch of the Brighton hornblende gabbro complex intrudes sheeted diabase dikes of the Lushs Bight Group on the east coast of Pilley's Island; however, the main exposures occur on Brighton Island and the smaller surrounding islands.

This unit is generally a very coarse grained hornblende gabbro with a complex history of multiple intrusion, with each phase being progressively less mafic. It is generally interpreted to be related to the ophiolitic magmatism.

Units 10 and 12 - Gabbro, Diorite and Granite

A number of bodies assigned to Unit 10 are intrusive into the Lushs Bight Group. They are considered to be of pre- Middle Ordovician age and comagmatic with the overlying Ordovician volcanic sequences. They vary in composition from gabbro and diorite to granodiorite and minor granite. They contain xenoliths and rafts of ultramafic rock varying in size from a few centimetres to >100 m.

Granitoid rocks (Unit 12) intrude the Lushs Bight Group and probably range in age from Silurian to Devonian. They consist of pink and red granite, alaskite, granodiorite and quartz-feldspar porphyry.

Structure

Early Structures

The Lushs Bight Group contains a single foliation which trends to the northeast or to the southeast and dips steeply, generally to the northwest or northeast. This fabric is commonly nonpenetrative in the pillow lavas where it is restricted to the pillow margins or the interstices. It is an L-S fabric associated with a steep stretching lineation and is defined by fine grained chlorite and fibrous amphibole. This foliation is axial planar to the regionally developed folds.

In the Pilley's Island and Triton Island areas, shallow northeast to southeast plunging folds with steep, locally overturned, northerly limbs and flat lying to shallowly south dipping limbs are well developed. These monoclinal folds are also considered to be related to the main deformation.

Chlorite schist shear zones are widely developed in the Lushs Bight Group. They form elongated or lenticular zones, from a few metres to more than 100 m wide, of coarse chlorite schist. These zones of chlorite schist pass into the normally weakly deformed host rocks with gradational contacts. This gradation occurs over a distance of one metre to tens of metres depending on the width and intensity of the shear zone. The rocks in these shear zones are totally schistose so it is generally difficult to determine the protolith. Dikes in these zones are transposed into the plane of deformation and in places boudinaged. The schist zones are not lithologically controlled, although they parallel stratigraphy, and are both mineralized and barren. However, the schist zones are generally more highly pyritized than the country rocks.

The intensity of deformation and the development of chlorite schist zones gradually die out to the east, i.e. higher in the stratigraphy.

Kennedy and DeGrace (1972) demonstrated that the foliation in the chlorite schist zones is a composite fabric derived by folding and transposition of an earlier chlorite foliation. They further demonstrated that the chlorite schist zones resulted from the superimposing of a homogeneous deformational fabric on an older inhomogeneously developed fabric in shear belts. The regionally developed foliation in the Lushs Bight Group is thus the result of a second deformation (D_2).

Marten (1971b) mapped a series of faults having sinistral displacements subparallel to the regional foliation in the Western Arm area. He interpreted them to be slides related to the regional deformation. Kennedy and DeGrace (1972) also noted gently inclined faults, parallel to the trend of the regional formation, separating various units of the Lushs Bight Group in the King's Point area. Similar faults can be seen in the Lushs Bight Group in the study area.

Late Structures

Crenulations of the regional foliation (S_2) are present locally. These crenulations are folded by kinks/flexures and by major open folds. The axial planes dip steeply and trend approximately north-south. They are steeply plunging. The open folds do not affect the kinks/flexures and are interpreted to be contemporaneous with the kinks. These kinks/flexures and open folds are best developed in the chlorite schist zones, where they fold the schist. The regional structure (fabric and folds) is also folded about these late folds; this accounts for the change in regional trends from northeast to southeast.

A number of postfolding major faults transect the Lushs Bight Group in this area. The most prominent are the Deer Pond Fault, the Little Deer - Davis Pond Fault system, the Gull Pond Fault and the Sullivan Pond Fault. Numerous splays and subsidiary faults are related to these. Similar faults in the Western Arm area are believed to have mainly dextral strike-slip movements because of their large horizontal components, straightness and lateral continuity (MacLean, 1947; Marten, 1971b). Similar dextral strike-slip movement is inferred for the faults in this area on the basis of evidence along the Davis Pond Fault and the 4 km dextral offset of the Lobster Cove Fault (MacLean, 1947; Neale and Nash, 1963); however, a component of dip-slip movement is also present. Many of the faults appear to have removed the axial zones of the major folds in the region. Narrow, less intense shear zones, breccia zones and brown carbonate breccia zones accompany the faulting.

Metamorphism

The Lushs Bight Group is characterized by epidote alteration which commonly completely replaces the cores of the pillow lava. This alteration predated or accompanied the regional deformation. It decreases upwards in the sequence and generally dies out near the top of the Lushs Bight Group, which is generally characterized by black, commonly hematized basalt, with epidote occurring only as minor veins and irregular patches.

Marten (1971a,b) referred to the two different types of lava within the Lushs Bight Group as the "main facies" and the "black facies". The "main facies" is composed of green and gray-green, epidotized mafic lavas and is characteristic of the lower parts of the Lushs Bight Group. The "black facies" is composed of black, fresh to chloritic lava with epidote as veins and irregular patches. It is concentrated in the upper parts of the Lushs Bight Group but has no formational status. Marten (1971b) suggested a correlation with the "Whalesback type" and "St. Patricks type" lava divisions, respectively, proposed by Papezik and Fleming (1967) for the volcanic rocks in the Whalesback mine area.

Studies of metamorphism in ophiolites (e.g. Spooner and Fyfe, 1973) indicate that the intense alteration and metamorphism of lower pillow lava units prior to deposition of upper pillow lava units is a common phenomenon. This is postulated to result from subseafloor hydrothermal metamorphism at active spreading ridges. The alteration facies developed in the Lushs Bight Group is thus interpreted to be a 'primary' alteration feature developed during the formation of the ophiolite.

Metamorphism related to the regional deformation was mainly limited to growth of chlorite and fibrous amphibolite along the foliation. It decreases upwards in the stratigraphy and had little effect on the overlying sequences.

Mineralization

The Lushs Bight Group contains more base metal sulfide showings per square kilometre than any other group of rocks in Newfoundland (Dean, 1978). The group has been extensively prospected, and has seen the development of two mines, Little Bay and Whalesback, and about two dozen prospects.

The many deposits differ greatly in size but most have several features in common which were noted by earlier workers. All are roughly ellipsoidal, with their long axes approximately coplanar with bedding. They occur almost exclusively in chlorite schist shear zones developed in pillow lavas (Peters, 1967) and associated tuff. These zones of schist and parallel sulfide lenses are conformable with the stratigraphy. They consist mostly of pyrite with lesser amounts of chalcopyrite, pyrrhotite and sphalerite and minor values of gold and silver.

Douglas et al. (1940) and MacLean (1947) considered the deposits to be replacements of chlorite schist in the shear zones during the late stages of faulting, and thus to have a common origin. MacLean also suggested a genetic relationship between the sulfides and granodiorite in the area. Williams (1963) concluded that a genetic relationship to volcanism might exist but that the final emplacement and distribution of the sulfides postdated the volcanism and resulted from structural deformation. Kanehira and Bachinski (1968) concluded that the sulfide mineralization at least in part predated deformation and metamorphism but also must have postdated the volcanism. West (1972) concluded that the mineralization at the Little Deer mine was postvolcanic.

Kennedy and DeGrace (1972) considered the deposits to predate the main regional deformation (D_2) because pyrite bands are commonly folded about the associated folds and chalcopyrite is concentated in fold hinges. In the Whalesback area, the sulfides are cut by the predeformation porphyry dikes (Fleming, 1970). Kennedy and DeGrace (1972) observed that, in most showings, banding resembling layering is present and that, with the exception of the Whalesback and Little Bay mines, the deposits occur in layered tuffaceous rocks. They thus concluded that the mineralization was synvolcanic.

Twenty-one volcanogenic sulfide showings and prospects visited during the 1983 field season are described in this report. They are described under four headings: (1) in the sheeted dikes; (2) near the sheeted dike - pillow lava contact; (3) within pillow lava and intercalated tuff of assumed higher stratigraphic position; (4) in sediments at the top of pillow lava.

(1) Mineralization in the sheeted dikes

A number of small showings, including the Indian Beach and Head (Keatons Adit), occur within narrow chlorite schist zones within sheeted dikes.

The *Indian Beach prospect (#21)*, located near Indian Head, Halls Bay, occurs in a sequence of northwest trending, southwest dipping sheeted diabase dikes. An old shaft and a dump with one to two tonnes of hand-sorted ore are present at the prospect. MacLean (1947) reported that a sample from about twenty pieces of this ore assayed 3.86% Cu, trace Au and 0.07 oz. Ag per short ton (2.4 g/t). The mineralization occurs in a northwest trending, steeply northeast dipping chloritized shear zone in narrow bands over a width of 2 to 3 m; it consists of disseminated and stringer pyrite, chalcopyrite and pyrrhotite.

The *Indian Head* or *Keatons Adit showing (#22)* occurs in the same sheeted dike sequence approximately 1 km southwest of the Indian Beach prospect. The showing consists of disseminated pyrite and minor chalcopyrite in a narrow, chloritized and minor silicified shear zone. Malachite staining is present in the cliffs along the coast. There are no grade or tonnage data available for this prospect.

The *Hearn gold prospect (#17)* at Little Bay, described by Kean (1983), also occurs within the sheeted dike zone and a number of small showings occur in the sheared sheeted dike sequences on Sunday Cove Island.

(2) Mineralization near the sheeted dike - pillow lava contact

Four major deposits occur in pillow lava within a few hundred metres of the sheeted dike - pillow lava contact. They are the *Little Bay* and *Sleepy Hollow deposits (#16)* (see Kean, 1983), and the Lady Pond and Miles Cove Mine deposits. The *Little Bay Head (#19)* and *Shoal Arm (#20) showings* are small prospects that probably occur in a similar setting. They occur in pillow lava with common to extensive diabase dikes. The *Paddox Bight showing (#25)*, located on the north side of Paddox Bight, Sunday Cove Island, occurs in dikes with minor pillow screens; it consists of a cluster of shafts and pits with small ore dumps. Howse and Collins (1979, Table II) reported a grab sample assay of 12.0% Cu, 25 g/t Pb, 0.12% Zn, and 0.2 g/t Au. The mineralization consists of pyrite and chalcopyrite as stringers and disseminations in altered and chloritized diabase dikes with a few pillow lava screens.

The *Lady Pond prospect (#13)*, consisting of seven or more shafts, is situated at the east end of Lady Pond approximately 1.5 km south of Davis Pond. MacLean (1947) described the old mine workings. Mineral deposit files at the Newfoundland Department of Mines and Energy describe the history of exploration and development, and report assays of 0.62% to 2.59% Cu in drill core. Traces of gold and silver were noted in some holes.

The prospect is in variolitic and quartz amygdaloidal pillow lava and breccia with extensive diabase dikes, approximately 200 m above the sheeted dike - pillow lava interface. In places, diabase dikes constitute up to 60% of the exposure. Intense silicification and possibly minor felsic tuff are also present in the mineralized zone. Shearing is locally well developed.

Very little mineralization is exposed on the surface, except for thin lenses of magnetite and magnetite-rich black interpillow chert and disseminated pyrite in chloritic mafic volcanics. Samples from the dumps vary from massive magnetite with minor quartz and chalcopyrite to stringers and disseminations of pyrite, chalcopyrite and pyrrhotite in chlorite schist. There are no massive sulfides exposed or in samples in the dump. However, MacLean (1947) reported that the ore was evidently in the form of individual, small lenses.

The ***Miles Cove Mine prospect (#23)*** is located at Miles Cove, Sunday Cove Island. The prospect has had a long and varied exploration history extending from the late 1800's to the late 1960's (see Howse and Collins, 1979). Three shafts, several pits and an old dump mark the abandoned workings. The prospect was estimated by Howse and Collins (1979) to contain 199,800 metric tonnes of 1.45% Cu. The prospect also assayed 0.34 g/t Au and 12.0 g/t Ag (Ten Cate, 1957).

The deposit is located in chlorite schist within pillow lavas and dikes a few hundred metres above the sheeted dike - pillow lava interface. Surface exposures consist of a 20 to 25 m wide, intensely chloritized schist zone with disseminated and stringer pyrite and minor chalcopyrite. Extensive quartz veins and knots cut the schist and are generally coplanar with the foliation. Small quartz eyes, possibly amygdules, are common in the top part of the chlorite schist. The chlorite schist grades into deformed basaltic pillow lava. The schist is kinked and crenulated about a vertical north-south axial plane. Narrow beds or lenses of tuff are also reported from this sequence. The sequence is intruded by diabase dikes and a felsic quartz-feldspar porphyry dike.

The mineralization consists of disseminations, blebs and stringers of pyrite, chalcopyrite and minor gold, silver and magnetite in the chlorite schist. Howse and Collins (1979) determined from drill sections that the mineralized shear zone has a strike length of 100 m and an average width of approximately 8 m.

There is no evidence of exhalative mineralization in the surface exposures and trenches. However, reports of the early workings indicate bands and lenses ranging in thickness from 0.3 to 1.0 m and up to 20 m long (Douglas et al., 1940). They also reported the presence of massive, banded, cupriferous pyrite on the ore dumps.

(3) Mineralization within pillow lava and tuffs

Much of the mineralization in the Lushs Bight Group that occurs in pillow lava and intercalated tuffs does not appear to have a close spatial association to the sheeted dikes. The most prominent of this type of mineralization is in the ***Whalesback (#15)*** and ***Little Deer (#14)*** mines (see Kean, 1983), and the Rendell-Jackman, Colchester, and McNeily prospects. The Sterling prospect is also grouped with these but it may be close to the sheeted dike - pillow lava interface. There are numerous other smaller prospects and showings that also occur in chlorite schist.

The ***Sterling prospect (#11)*** is located about 1.5 km northwest of Springdale. The property was developed in the 1880's and has been the subject of geological and exploration investigations ever since. The property has two shafts and several test pits. The reader is referred to McArthur (1973) for further details. There is no reliable estimation of tonnage. McArthur (1973) gave grades and widths for a number of holes cutting the mineralization. He noted the lack of continuity from hole to hole and the generally narrow width (<2 m) of the mineralization. He reported the best section as 1.7% Cu over 14 m.

The Sterling prospect occurs in mafic volcanics with an intercalated felsic tuff unit. The mafic volcanics are locally highly amygdaloidal and variolitic. The mafic volcanics consist of chloritic and epidotized basalt, pillow basalt, isolated pillows and pillow breccias and minor tuffs. The felsic tuffs are fine grained to aphanitic, green, dacitic-looking rocks, with or without quartz amygdules. A number of smaller showings occur in similar felsic or intermediate composition rocks in Unit 3C. Chert and jasper occur as small patches and lenses ranging from a few millimetres to 60 cm.

Numerous bodies of diabase and gabbro intrude the sequence. It is not uncommon for dikes to constitute 40 percent of one outcrop. Locally, to the southwest of the prospect, sheeted diabase dikes are present in isolated outcrops. Therefore, the Sterling prospect may in fact be closely associated with the sheeted dike - pillow lava interface.

Surface exposures of the mineralization consist of disseminated and stringer pyrite and chalcopyrite in chlorite schist. McArthur (1973) described two separate zones of pyrite and chalcopyrite mineralization with minor pyrrhotite and sphalerite. He described the sulfide bodies as massive or nearly massive lenses and pods and as stockworks of stringers and disseminations. The mineralized zones are in steeply dipping chlorite schist layers that are generally conformable with the regional trend. Quartz and carbonate veins are generally present. McArthur (1973) interpreted the Sterling prospect to be a stockwork zone.

The ***Sullivan prospect (#12)*** lies approximately 1 km to the east of the Sterling prospect. It consists of disseminations and stringers of pyrite and chalcopyrite and extensive veinlets of quartz in chlorite schist. The mineralized zone has a strike length of 1.5 km and varies from 70 to 140 m wide.

The *Rendell-Jackman prospect (#9)* is located approximately 1.2 km south of the bottom of Southwest Arm. It has been the subject of intense investigations since its discovery in the early part of this century. Three shafts have been sunk in the prospect, one in the northern zone and two in the southern zone. There are no up-to-date estimates of grade and tonnage. However, in 1912, proven reserves in the northern lens amounted to approximately 11,000 tonnes at an unspecified grade. Grades from the early production averaged 4% Cu. Since then, assays of grab samples from the dump and of drill core have varied from 1 to 5% Cu. An average grade of 0.72% Cu and 0.03 oz./ton Au over 61 feet (1.0 g/t over 19 m) was reported by MacLean (1947) for the government drilling on this property. The reader is referred to DeGrace (1971) and Douglas et al. (1940) for more details.

The prospect consists of two lenses or mineralized zones within chlorite schist. The chlorite schist is developed in tuff within a pillow lava - pillow breccia sequence. Minor jasper lenses occur in the mineralized schist zones. Surface exposures consist of chlorite schist with disseminations and stringers of pyrite. Diabase and gabbro dikes are common. Quartz veins and knots are present but not extensive. MacLean (1947) noted two types of mineralization. Massive banded pyrite with minor chalcopyrite and rare sphalerite and magnetite are characteristic of the southern zone; 'nodular' massive chalcopyrite and minor pyrite in chlorite schist are characteristic of the northern zone. The banding is defined by sulfide composition and by grain size. The banding is on a scale of 1 cm or less. Boudinaged jasper lenses occur in the mineralized zones. MacLean (1947), however, reported beds up to 6 feet (1.8 m) in thickness. The 'nodular' mineralization consists of nodules or lenses of chalcopyrite up to 10 cm in diameter in the chlorite schist. Tiny veinlets of chalcopyrite also cut the chlorite schist. Granular and cubic pyrite are not extensive. This suggests that the northern, more chalcopyrite-rich, mineralization is of stockwork type, while the southern, banded, pyritic mineralization represents the exhalative facies.

A few kilometres to the south of the Rendell-Jackman, several small showings occur in a predominantly bedded tuff and argillite sequence with intercalated mafic volcanics (Unit 4). These showings are best represented by the *Yogi Pond - Yogi Pond North* and *Nolan prospects (#10)*. They all occur in chlorite schist or mafic volcanics. The mineralization occurs as bands of disseminated pyrite and locally minor chalcopyrite. In places, banded or bedded pyrite with magnetite bands up to 2.5 cm thick are well developed. Magnetite chert and magnetite-rich sediment/tuff are locally developed throughout the unit in which this mineralization occurs.

The *Jerry Harbour prospect (#24)*, located at the bottom of Jerry Harbour, Sunday Cove Island, consists of a series of trenches. Two chip samples taken from a 1 m wide sulfide vein average 2.52% Cu, 0.26% Zn and 0.85 g/t Au (Howse and Collins, 1979).

The mineralization occurs in schistose tuffs, agglomerates and minor red chert within pillow lava. The mineralization consists of bands, stringers and disseminations of pyrite and minor chalcopyrite. In one trench, a 1 m wide band of massive sulfide and stringers of pyrite and chalcopyrite are associated with quartz veinlets in chlorite schist. Magnetite is also present. Quartz veining, silicification, pyritization and minor sericite is commonly developed in the surrounding mafic volcanic sequence. The pillow lava is also quartz amygdaloidal and locally variolitic.

A number of small showings, e.g. *Swatridge and Swatridge East (#4)*, *Old English (#5)*, and *South Naked Man (#6)*, occur in chlorite schist adjacent to the Colchester Pluton. The mineralization occurs mainly as disseminations and stringers in chlorite schist and in quartz veins cutting the schist. Pyrite, chalcopyrite and pyrrhotite are the main sulfide minerals. All of these showings have shafts and/or trenches on them. The most significant of these showings is probably the Old English. Copper values vary from <0.50% to >2.0% over short distances. The reader is referred to Gibbs (1967) and McArthur (1971) for further details.

The *McNeily (#8)* and *Colchester (#7) prospects* occur along the southwest side of the Colchester Pluton and are somewhat more significant than the other showings. These prospects were developed in the last century and have been subject to a number of exploration and geological studies since then (see McArthur, 1971).

The Colchester Main Zone comprises an 85 m wide chlorite schist zone mineralized over a distance of 485 m. Three shafts and an adit have been developed on the property. Gibbs (1967) estimated the tonnage at 1 million tons of 1.3% Cu. The West Zone has a shaft and a number of trenches sunk on it. No significant tonnage or grades have been reported for this prospect.

The Colchester Main and West Zones consist of pyrite and chalcopyrite mineralizaion in a chlorite schist zone. The mineralization occurs as disseminations, blebs, stringers, veins and irregular masses in the chlorite schist. Quartz-carbonate veins also carry sulfide mineralization. Pyrrhotite and magnetite are present. The chlorite schist occurs in pillow lava, breccia and agglomerate. Extensive dikes ranging from gabbro and diabase to felsite and quartz porphyry are common in the area.

The McNeily prospect occurs approximately 1000 m southwest of the Colchester Main Zone. Three shafts have been sunk on this prospect and it has been extensively diamond drilled. However, no significant tonnage has been outlined and grades vary from <0.5% to about 4% Cu over short intervals. Chalcopyrite and pyrite occur in a chlorite schist zone from 30 to 100 m wide. The schist zone occurs within a distinctive mafic breccia/agglomerate unit within the pillow lava. Magnetite-rich black chert and small magnetite pods are present in the chlorite schist. The agglomerate and breccia clasts are generally highly variolitic and quartz and/or calcite amygdaloidal. Extensive pyrite is locally present in the matrix. Intense leaching and silicification to a white felsic breccia appearance is developed in the vicinity of some of the mineralization. Dikes of gabbro, diorite, felsite, and feldspar porphyry are common. Quartz and quartz-chlorite veins are locally common.

McArthur (1971) reported the mineral assemblages as follows: pyrrhotite-pyrite-chalcopyrite, banded pyrite-chalcopyrite-sphalerite-magnetite.

(4) Mineralization in sediments at the top of Lushs Bight Group

Several significant showings occur in sediments at the top of the Lushs Bight Group. They are the ***Nickey's Nose (#1), Rushy Pond (Wheelers Shaft) (#2), Rushy Pond Head (#3)*** and ***Fox Neck (#18).***

The top part of the Lushs Bight Group is characterized by being black rather than green, and less altered and/or more chloritic than epidotized. Epidote occurs as veins and fracture fillings. Interpillow red chert or jasper is common and forms large lenses in places. Magnetite is common as disseminations and discrete bands in the chert. In places, the magnetite forms lenses up to 0.5 m thick. Overlying these jasper-rich pillow lava, breccia and agglomerate sequences is a sequence of chocolate brown argillite with interbedded thin jasper lenses and black argillite-mudstone. This sedimentary sequence can, in places, be as much as 150 m thick; however, thickness is complicated by faulting and folding.

Bands of massive pyrite and pyrrhotite with minor magnetite occur within the black argillite-mudstone. At Nickey's Nose, the mineralized zone is approximately 10 m wide and is exposed for about 100 m. The mineralization in the Nickey's Nose area occurs at two different places (Nickey's Nose North and South) that are interpreted to be structurally repeated. A shallow shaft was sunk on this showing and about 25 short tons (22.7 tonnes) of massive sulfide ore were extracted (Lundberg, 1936). Douglas et al. (1940) reported 0.02 oz./ton (0.7 g/t) Au in a grab sample from all over this showing. Mineralization at Rushy Pond (Wheelers Shaft) and Rushy Pond Head occur at the same stratigraphic level and is of the same type. The Rushy Pond Head showing is traceable almost to Rushy Pond, a strike length of about 0.5 km. Old trenches and shallow shafts were sunk on these prospects; however, no grades or tonnages were reported.

The mineralization at Fox Neck occurs in the same stratigraphic position and consists of a 30 cm thick bed of pyrite and pyrrhotite and a band of magnetite a few centimetres thick with a strike length of about 10 m.

Immediately overlying this chocolate brown argillite are pyroxene crystal lithic tuffs and bedded tuffs of the Western Arm Group.

Summary and Conclusions

The Lushs Bight Group consists of a number of fault-bounded blocks, some of which contain an identifiable ophiolite stratigraphy. Chlorite schist zones within this sequence are early structures, not lithologically controlled, and are locally mineralized. The mineralized zones may have acted in part as zones of weakness along which shear zones developed.

The major sulfide deposits and showings in the Lushs Bight Group occur within chlorite schist zones. The schist zones are generally within pillow lava and/or intercalated pyroclastics, and are conformable with the enclosing rocks. The sulfide lenses are in turn conformable with the schist zones, although sulfide veins crosscut the chlorite schist.

The mineralogy is simple, and commonly there is a sharp hanging-wall contact and a gradational footwall contact. Deformation obliterated primary structures in most deposits, and the sulfides were remobilized and recrystallized. Therefore, any interpretation of paragenesis or mineral zoning is suspect.

Significant pyrite, pyrrhotite and magnetite mineralization occurs in the sediments at the top of the Lushs Bight Group.

There are several theories for the origin of the deposits in the volcanics, but the following evidence from this study suggests a syngenetic volcanic origin for the deposits: (a) they have an early, predeformational origin; (b) they are essentially conformable bodies in mafic volcanics of ophiolite affinity, i.e. they are strata-bound; (c) they possess a simple mineralogy that is similar to volcanogenic ophiolite deposits; and (d) the chlorite schist shear zones are interpreted as early tectonic features that did not control mineralization. However, there is no doubt that the deposits have been remobilized and recrystallized.

The chlorite schist shear zones have generally been considered as "controls" for mineralization. However, chlorite schist zones also occur in the pillow lavas that overlie the sheeted dikes of the Betts Cove Ophiolite Complex (Douglas et al., 1940; Upadhyay and Strong, 1973). Primary volcanogenic sulfide mineralization at the pillow lava - sheeted dike contact has been remobilized and redistributed along the schist zones (Kennedy and DeGrace, 1972). Duke and Hutchinson (1974) also described chloritic shear zones in the York Harbour mine area. They attributed them to late movement along a synvolcanic fault-fissure that controlled the distribution of ore deposition. However, the chlorite schist shear zones are conformable with stratigraphy and as such were probably subhorizontal zones at the time of their formation. The schist zones are thus interpreted as early shear belts which were initiated at points of greatest mechanical weakness, commonly, but not exclusively, the sulfide bodies and associated alteration zones. A similar conclusion was reached by DeGrace (1971) and Kennedy and DeGrace (1972) for the Lushs Bight Group in the King's Point area.

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B.F. Kean

MAJOR SULFIDE MINERALIZATION IN THE AREA

1. *Nickey's Nose:* Banded pyrite, pyrrhotite and magnetite in black mudstone interbedded with chocolate brown argillite and minor red chert.
2. *Rushy Pond:* same as Nickey's Nose.
3. *Rushy Pond Head:* same as Nickey's Nose.
4. *Swatridge and Swatridge East:* Disseminated and stringer pyrite and chalcopyrite in narrow chlorite schist zones in pillow lava.
5. *Old English:* Stringer and disseminated pyrite and chalcopyrite with minor sphalerite in chlorite schist and quartz veins along the contact with the Colchester Pluton.
6. *South Naked Man:* Pyrite and chalcopyrite in chlorite schist.
7. *Colchester and Southwest Colchester:* Disseminations, stringers and lenses of pyrite, chalcopyrite and pyrrhotite with minor sphalerite in altered pillow lava and breccia.
8. *McNeily:* Disseminations, stringers and bands of pyrite, chalcopyrite and pyrrhotite with minor sphalerite in chlorite schist.
9. *Rendell-Jackman:* Pyrite, chalcopyrite, minor sphalerite and magnetite in chlorite schist derived from tuff.
10. *Yogi Pond and Nolan:* Banded massive pyrite and magnetite in schistose tuff.
11. *Sterling:* Pyrite and chalcopyrite with minor sphalerite as massive lenses, pods, stringers and disseminations in chloritic pillow lava and felsic tuff.
12. *Sullivan Pond:* Disseminated and stringer pyrite and chalcopyrite in chlorite schist.
13. *Lady Pond:* Disseminations, stringers and lenses of pyrite, chalcopyrite and magnetite in pillow lava, altered breccia and schist with extensive diabase dikes.
14. *Little Deer:* Pyrite, chalcopyrite, pyrrhotite and sphalerite as disseminations, stringers, lenses and pods in chlorite schist in pillow lava.
15. *Whalesback:* Pyrite, chalcopyrite, pyrrhotite and sphalerite as disseminations, stringers and banded lenses and pods in chlorite schist in pillow lava.
16. *Little Bay and Sleepy Hollow:* Pyrite, chalcopyrite, pyrrhotite and magnetite as massive lenses and pods, as stringers and disseminations in chlorite schist within pillow lavas and diabase dikes.
17. *Hearn:* Pyrite, chalcopyrite, sphalerite, arsenopyrite, galena and gold in quartz veins and as stringers and disseminations in sheared sheeted dikes with minor pillow screens.
18. *Fox Neck:* Banded pyrite, pyrrhotite and magnetite beds in chocolate brown argillite and red chert.
19. *Shoal Arm:* Pyrite, chalcopyrite, pyrrhotite, sphalerite and arsenopyrite in chlorite schist in pillow lava and diabase dikes.
20. *Little Bay Head:* same as Shoal Arm.
21. *Indian Beach:* Pyrite, chalcopyrite and pyrrhotite in chlorite schist within sheeted diabase dikes.
22. *Indian Head (Keatons Adit):* same as Indian beach.
23. *Miles Cove:* Pyrite and chalcopyrite in chlorite schist in pillow lava above sheeted dike contact.
24. *Jerry Harbour:* Pyrite and chalcopyrite in chlorite schist derived from tuff intercalated with pillow lava.
25. *Paddox Bight:* Pyrite and chalcopyrite disseminations and veins in sheeted dikes with pillow screens.

GEOLOGIC SETTING AND VOLCANOGENIC SULFIDE MINERALIZATION OF THE EASTERN WILD BIGHT GROUP, NORTH-CENTRAL NEWFOUNDLAND

by

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Mineral Deposits Section

Also in Current Research, Part A, Geological Survey of Canada, Paper 84-1A.

Abstract

The Wild Bight Group in north-central Newfoundland is a thick sequence of volcaniclastic, volcanic and related intrusive rocks deposited during the development of an Early-Middle Ordovician island arc. Volcanic flows, which comprise up to 20% of the sequence, are dominantly basaltic and occur at several stratigraphic levels. Rhyolitic flows and pyroclastics are locally developed in the central part of the succession. Volcaniclastic rocks consist of fine grained sandstone, siltstone and chert interbedded with thick conglomerate units. Sedimentary structures suggest a northerly flow. The environment appears to have been one of quiet sedimentation on the flanks of a volcanic edifice to the south, punctuated by periodic debris flows and local eruptive activity.

Four volcanogenic sulfide deposits are known in the Wild Bight Group. The largest of these, the Point Leamington deposit, comprises a massive sulfide body underlain by a zone of pervasive quartz-sericite and chlorite alteration. The Lockport deposit outcrops as a stockwork zone but there is evidence of a small massive cap in the subsurface. The Indian Cove and Long Pond prospects are pyrite-chalcopyrite-bearing stockwork zones. All are spatially and stratigraphically associated with felsic volcanism.

Introduction

The Wild Bight Group comprises a thick sequence of volcanic and sedimentary rocks which outcrop across Notre Dame Bay between Shoal Arm, Badger Bay and Osmonton Arm, New Bay (Figure 1). The sequence is overlain by Caradocian chert and shale and is considered by most workers (e.g. Dean, 1978) to form part of an Early-Middle Ordovician island arc, remnants of which are preserved throughout central and southern Newfoundland (Kean et al., 1981; Swinden and Thorpe, in press).

The general distribution of lithologies and their stratigraphic sequence within the Wild Bight Group was first investigated in detail in the 1930's. Heyl (1938) mapped the sequences immediately adjacent to New Bay as part of his comprehensive examination of the stratigraphy of the Bay of Exploits area, and Espenshade (1937) included part of what is now considered to be the western side of the Wild Bight Group in his study of the Pilleys Island area. Each worker erected a local stratigraphic nomenclature in his area, and Espenshade appears to have been the first to coin the term "Wild Bight volcanics" for the sequences exposed in Wild Bight, Badger Bay. Hayes (1951) later mapped part of the western Wild Bight Group, assigning these rocks to the "Exploits Series" but retaining the term "Wild Bight Formation" for the sequences in Wild Bight.

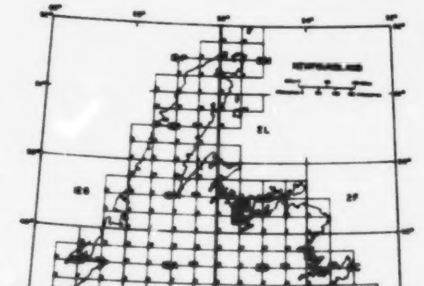


Figure 1: *Location of the study area. Black square is the area shown in Figure 2.*

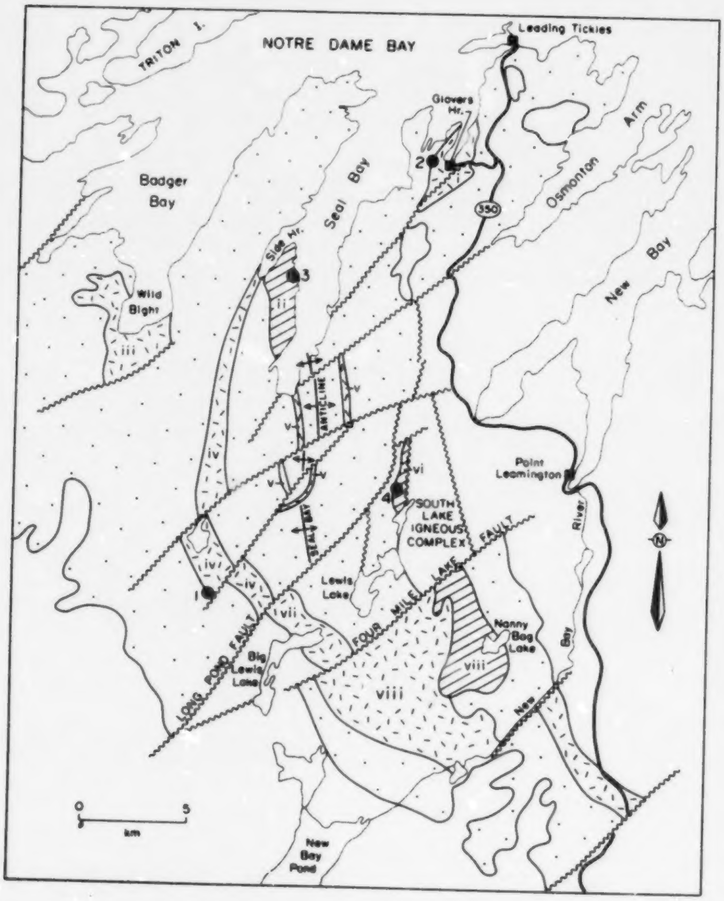
Contribution to the Canada-Newfoundland co-operative minerals program 1982-84. Project financed by the Geological Survey of Canada.

The "Wild Bight Group" in its present form was defined by Williams (1963) during his 1:250,000 mapping of the Botwood (2E) map area.

The most detailed published maps of the Wild Bight Group are those compiled by Dean (1978) at a scale of 1:50,000. Wild Bight Group data on these maps were drawn principally from the workers cited above and from unpublished exploration company maps. Dean's (1978) contribution to the geology of the Wild Bight Group was two-fold. Firstly, and perhaps most importantly, he provided the first detailed published account of the distribution of the group. Secondly, he subdivided it into five informal formations, providing a stratigraphic framework within which the distribution of the various volcanic sequences could be interpreted.

Volcanogenic sulfide mineralization in rocks presently assigned to the Wild Bight Group was first discovered in the late 1800's near Lockport. The deposit there was worked briefly around the turn of the century, yielding the only recorded production from the Wild Bight Group. Since that time, three other deposits of volcanogenic origin have been recognized in the sequence, the Indian Cove and Long Pond prospects and the Point Leamington deposit (Figure 2).

The present study was designed to investigate the regional geologic and tectonic setting of the Wild Bight Group, with emphasis on the volcanic rocks which occur principally in the eastern part of the group, and the four volcanogenic sulfide deposits which they host.


TRITON I.
NOTRE DAME BAY
Leading Tickles
Glovers Hr.
Badger Bay
Seal Bay
Osmonton Arm
350
New Bay
Side Hr.
Wild Bight
iii
ii
ANTICLINE
SEAL BAY
Point Leamington
SOUTH LAKE IGNEOUS COMPLEX
FOUR MILE LAKE FAULT
LONG POND FAULT
Lewis Lake
Big Lewis Lake
Nanny Bog Lake
River
New Bay
New Bay Pond
i
iv
v
vi
vii
viii
1
2
3
4
N
0
5
km

LEGEND

⁙ Mainly volcaniclastic and sedimentary rocks.

⁘ Mainly mafic volcanic rocks.

▨ Mainly felsic volcanic rocks.

KEY TO VOLCANIC SEQUENCES
(see text; most designated names are informal)

i	Glovers Harbour basalts.
ii	Indian Cove volcanics.
iii	Wild Bight, Badger Bay volcanics.
iv	Side Harbour formation north of Long Pond fault.
v	Sparrow Cove Point formation.
vi	Long Pond volcanics.
vii	Big Lewis Lake basalts.
viii	Volcanic rocks between Four Mile Lake fault and New Bay River

KEY TO VOLCANOGENIC SULFIDE DEPOSITS

1	Point Leamington
2	Lockport
3	Indian Cove
4	Long Pond

Figure 2: *Simplified distribution of lithologies in the eastern Wild Bight Group. Location of volcanogenic sulfide occurrences is indicated by solid circles.*

Geologic Setting of the Eastern Part of the Wild Bight Group

Dean (1978) showed that the Wild Bight Group occupies a broad anticlinal structure, the axis of which trends approximately north-south through the center of Seal Bay (the Seal Bay anticline, Figure 2). The base of the sequence is not exposed in this area: the stratigraphic succession youngs more or less continuously to the east and west (although crossing numerous minor folds) and eventually passes conformably upward into fossiliferous Caradocian shale and chert of the overlying Shoal Arm Formation. Two virtually complete cross-sections of Wild Bight Group stratigraphy are exposed on the coastline between Shoal Arm and the Leading Tickles peninsula on both sides of the Seal Bay anticline, and well washed exposures display the essential features and critical relationships of the sequence. The author feels that systematic mapping of this area will ultimately result in considerable revision of Dean's (1978) informal stratigraphic nomenclature. Accordingly, this nomenclature will be used sparingly in the following discussions.

In general terms, three rock types are present in the eastern Wild Bight Group: (1) volcaniclastic and sedimentary rocks, (2) volcanic rocks, and (3) mafic intrusive rocks. These are briefly described below; because of the economic significance of the volcanic rocks, they are treated in more detail.

(1) Volcaniclastic and Sedimentary Rocks

Volcaniclastic and sedimentary rocks comprise up to 80% of the Wild Bight Group succession. In the eastern Wild Bight Group, these are principally of two types: (i) fine grained, planar bedded, laminated graywacke, siltstone, argillite and chert with local conglomerate beds; and (ii) massive, generally unbedded, medium to coarse grained volcaniclastic conglomerate. The latter is generally matrix-supported, often poorly sorted, and contains subrounded to angular fragments of locally derived volcanic and sedimentary rocks.

Some general comments can be made concerning the stratigraphic development of sedimentary rocks in the eastern Wild Bight Group. The oldest unit, exposed in the core of the Seal Bay anticline, consists of up to 500 m of fine grained argillite, siltstone and chert with minor amounts of pebble sandstone and rare fine grained conglomerate. This stratigraphic unit, referred to as the Omega Point formation by Dean (1978), is characterized by abundant green to buff chert and particularly by red chert and argillite. It contains a single 6 m thick black shale horizon exposed on a small island in Seal Bay bottom, and appears to record the most extensive interval of quiet water sedimentation in the Wild Bight Group. Along the eastern shore of Seal Bay, this unit passes upward into a volcaniclastic succession containing increasing amounts of coarse volcaniclastic sandstone and conglomerate horizons. Immediately north of Sparrow Cove Point, these lithologies typically form 0.3 to 5 m beds separated by a similar thickness of fine grained, laminated chert and siltstone. The thickness and abundance of the coarse units increase northward along the east side of Seal Bay (i.e. upsection); in the area north of Locks Harbour, individual layers of coarse volcaniclastic conglomerate commonly attain thicknesses greater than 60 m, separated by 1 to 10 m layers of fine grained siltstone and chert. These coarse sediments form a major part of the sequence up to its exposed top on the Leading Tickles peninsula. A similar progression from fine grained, apparently quiet water sedimentation through environments of progressively more coarse deposition by debris flows and turbidite currents is also recorded in sequences on the west side of the Seal Bay anticline, although local structural complications and probable facies changes make detailed correlation difficult.

The environment recorded by the Wild Bight Group succession appears to have changed from initial quiet water sedimentation to quiet sedimentation punctuated by periodic turbidity currents and debris flows. Current ripples, crossbeds and slump structures indicate a generally northerly flow, suggesting a topographic high to the south. Therefore, the sediments were probably deposited on the middle flanks of a volcanic edifice situated to the south.

(2) Volcanic Rocks

Volcanic accumulations are present at several localities and various stratigraphic levels within the eastern Wild Bight Group (Figure 2). All the known volcanogenic sulfide deposits in the Wild Bight Group are hosted by volcanic rocks, although not all volcanic accumulations are known to be mineralized. Each major volcanic sequence is described briefly below; names for these sequences are for convenience only and do not represent formally proposed stratigraphic nomenclature.

(a) Descriptions

(i) *Glovers Harbour volcanics:* The Glovers Harbour volcanics, host to the Lockport deposit, were included in the Pennys Brook Formation by Dean (1978). They

consist predominantly of pillow basalts, which comprise 60 to 70% of the section. The pillows are generally 0.7 to 1.5 m long, bulbous to somewhat flattened and highly vesicular, the vesicles commonly filled with chlorite, calcite or epidote. Most pillows have well developed rinds, and minor hyaloclastic material occurs in the interstices. Well washed coastal outcrops provide good three dimensional exposure of pillows and allow top determinations to be made with confidence.

Most of the remaining lithologies in this unit are volcaniclastic and hyaloclastic. Well bedded volcaniclastic sandstones are locally interbedded with the pillow lavas. The eastern part of the sequence contains a 200 m thick lens of basaltic pyroclastic rock containing abundant fragments of basalt in a chloritic matrix; the lens outcrops on islands and headlands in the central and eastern parts of Glovers Harbour. Pillow breccias are locally developed throughout the sequence.

A single felsic volcanic member outcrops on several rocky hills about 700 m south-southwest of the Lockport mine. This unit consists of gray to bluish, quartz-feldspar crystal tuff and possibly represents a single ash flow. It appears to lie at approximately the same stratigraphic horizon as the Lockport mine.

Minor amounts of red chert are present in the sequence. One particularly persistent bed up to 1 m thick can be traced for more than 800 m along strike immediately north of the Lockport mine.

The Glovers Harbour volcanics are faulted against well bedded chert, argillite and sandstone to the west along a fault which is apparently dextral strike-slip. Adjacent to the fault, the basalts are intensely cleaved and hematized, and face northwest. To the east, the volcanics pass conformably upward into coarse volcaniclastic debris-flow deposits; the contact is exposed on the shoreline northeast of Glovers Harbour.

Structural relationships within the volcanics have not been mapped in detail. They appear, however, to occupy a broad anticlinal structure, the axis of which trends north-northwest immediately west of Glovers Harbour.

(ii) Indian Cove volcanics: The Indian Cove volcanics, host to the Indian Cove prospect, were assigned to the Seal Bay Brook formation by Dean (1978). They occupy an area approximately 4 km long and 1 km wide between Side Harbour and Mill Cove and consist of a complex assemblage of volcanic flows and pyroclastic rocks. The central and probably oldest part of the Indian Cove volcanics consists of a massive, buff to green rhyolite which outcrops on the north shore of Indian Cove and in the hills west of the cove. The rhyolite is massive and commonly displays intense hydrothermal alteration characterized by gas brecciation and closely spaced fractures filled with hematite and pyrite. The rhyolite is overlain by various types of felsic to mafic pyroclastic rocks displaying rapid lateral facies changes. These consist mainly of poorly sorted, angular fragments of felsic volcanic rock, chert and minor basalt set in a tuffaceous matrix varying from dark green to buff in color and mafic to felsic in composition. Spectacular breccias are present locally; they contain red chert fragments up to 5 m across chaotically distributed in a gray to reddish chloritic matrix. These appear to represent debris flows, possibly related to the development of the domal structure represented by the rhyolite. The debris-flow deposits seem to occupy the upper stratigraphic levels of the volcanic sequence and pass conformably upward into well bedded red and green chert, siltstone and sandstone which mark the top of the unit.

A single pillow basalt flow is present in the southern part of the unit. It may occur low in the stratigraphy but, due to structural complications, this is uncertain.

The Indian Cove volcanics appear to pass conformably upward into volcaniclastic but and conglomerate to the west, although this contact is not exposed; the eastern contact lies under the waters of Seal Bay.

(iii) Wild Bight, Badger Bay volcanics: Mafic volcanic rocks outcropping around the bottom of Wild Bight, Badger Bay, were assigned to the Pennys Brook Formation by Dean (1978). They are composed mainly of basaltic, highly vesicular pillow breccias in which pillow fragments commonly range from 5 to 30 cm in diameter and possess well developed rinds on rounded surfaces. Complete pillows, locally preserved within the breccias, are both clast- and matrix-supported. Interstitial material, consisting of chloritic (probably hyaloclastic) matrix with abundant small angular basalt fragments, generally comprises less than 20% of the rock.

Thin pillowed flows are present but appear to comprise less than 20% of the sequence. The pillow lava units are 10 to 30 m thick, consisting of 1 to 1.5 m long pillows which generally contain abundant calcite- and chlorite-filled vesicles; they probably represent single flows. Locally, pillow lava can be seen to grade upward into pillow breccia.

The Wild Bight, Badger Bay volcanics are bounded top and bottom by volcaniclastic rocks and apparently lie near the top of the Wild Bight Group; the top is marked by the Caradocian Shoal Arm Formation to the immediate northwest.

Previous maps of this area (e.g. Espenshade, 1937; Dean, 1978) indicated that mafic volcanic rocks also outcropped along the east shore of Badger Bay northeast of Wild Bight, forming a 500 m thick unit from Green Point north to Little Cove, Badger Bay. This unit, in fact, consists of massive, dark green volcaniclastic sandstone with chert and basalt fragments, locally cut by fine grained mafic sills.

(iv) *__Side Harbour formation north of Long Pond Fault:__* This laterally extensive basaltic sequence hosts the Point Leamington sulfide deposit. It was assigned to the Side Harbour formation by Dean (1978). It is well exposed immediately south of Side Harbour, where it consists mainly of pillow lava, with large (30 to 50 cm), bulbous pillows which are commonly quite vesicular.

This formation is relatively thin immediately south of Side Harbour but thickens steadily southward along strike to a maximum of more than 2 km near the Point Leamington deposit. The basalt unit was previously mapped as outcropping in the bottom of Side Harbour (Figure 1). However, outcrops there consist of fine to medium grained mafic intrusive rocks which display chilled margins and contain xenoliths of adjacent rocks. These intrusive rocks are along strike from and probably represent a subvolcanic phase of the basalts.

The only felsic volcanics noted were in the immediate vicinity of the Point Leamington deposit, where quartz-feldspar crystal tuff forms a lenticular unit approximately 200 m thick which has been traced for more than 1500 m along strike.

The Side Harbour formation is bounded above and below by typical volcaniclastic lithologies of the Wild Bight Group. The contacts appear to be conformable, but are not exposed.

(v) *__Sparrow Cove Point formation:__* This formation consists of a thin (generally less than 100 m) unit of pillowed basalts, originally defined by Dean (1978). These basalts are moderately vesicular and outcrop in a horseshoe-shaped belt around the bottom of Seal Bay. This formation is probably misnamed since it does not appear to outcrop at Sparrow Cove Point, where the equivalent stratigraphic level is occupied by volcaniclastic sandstone and chert, and diabase and gabbro dikes and sills. However, the basalt is well exposed south of Seal Bay and is generally thin enough that it could represent a single flow. The basalt is conformably bounded on both sides by laminated chert, siltstone and graywacke.

(vi) *__Long Pond volcanics:__* This narrow unit of mainly rhyolite, quartz-feldspar crystal tuff, felsic pyroclastic rocks and red chert outcrops in a narrow, north trending band north of Lewis Lake. It hosts the Long Pond prospect and includes a narrow (30 to 40 m) unit of pillow lava and pillow breccia. The stratigraphic facing direction of this unit is not known; it is conformably bounded to the west by red chert and gray to green argillites which are in turn faulted against volcaniclastic rocks. To the east, the volcanics are faulted against the South Lake Igneous Complex.

(vii) *__Big Lewis Lake basalts:__* This sequence outcrops between the Long Pond and Four Mile Lake Faults, and can be distinguished from the Side Harbour formation basalts which adjoin them across the Long Pond Fault (Figure 2) in two respects: (1) the Big Lewis Lake basalts comprise mainly pillow breccia and basalt-bearing volcanic breccia with relatively little pillow lava; (2) they pass conformably upward into the Caradocian chert-shale interval and are, therefore, stratigraphically higher in the section. Both lithologically and with respect to their stratigraphic position within the Wild Bight sequence, the Big Lewis Lake basalts closely resemble the basaltic sequences in the Wild Bight, Badger Bay section. There are no felsic volcanics in this unit.

(viii) *__Nanny Bag Lake volcanics:__* Volcanic rocks in this area, assigned by Dean (1978) to the Pennys Brook formation, consist of a felsic volcanic complex centered on the west end of Nanny Bag Lake, bounded to the south and west by basalts which extend south to the New Bay River. The thick basaltic sequence west of the felsic complex comprises mainly massive, unpillowed, generally nonvesicular rocks unlike those anywhere else in the Wild Bight Group. The massive basalts are separated from the felsic complex by a narrow volcaniclastic graywacke and conglomerate unit which passes conformably eastward into the felsic complex. The felsic volcanic complex consists mainly of black to dark blue quartz-eye rhyolite and rhyolitic crystal tuff, but also contains a considerable amount of volcaniclastic material. Detailed traversing is needed to fully define the nature of this complex.

Geologic maps compiled by Dean (1978) show basaltic rocks outcropping southeast and east of the felsic volcanic center. The present mapping suggests that the south end of this volcanic sequence near New Bay River is underlain, at least in part, by diorite and gabbro intrusions. To the east of the felsic complex, volcaniclastic turbidites form all the outcrops. North of the Four Mile Lake Fault, mafic rocks east of the volcanic sequence appear to be intrusive and may be related to the South Lake Igneous Complex.

(b) Stratigraphic relationships

Volcanic rocks appear to occupy several stratigraphic levels within the Wild Bight Group. In some cases, the relative position of the volcanic rocks can be stated with confidence. In most cases, however, structural disruption and the paucity of outcrops in critical areas render correlations more uncertain. Present evidence suggests the following relationships:

(1) The Sparrow Cove Point basalts (v) are the stratigraphically lowest volcanic rocks in the sequence, occurring near the exposed base of the Wild Bight Group in the core of the Seal Bay anticline.

(2) The Big Lewis Lake basalts (vii) are the stratigraphically highest volcanic rocks in the sequence and pass directly upward into Caradocian shale and chert. The Wild Bight, Badger Bay basalts are only slightly lower in the sequence, separated from the Caradocian shales of the Shoal Arm Formation by a thin volcaniclastic interval. These two basaltic sequences are very similar lithologically, consisting dominantly of pillow breccia and hyaloclastite with minor pillowed flows. They are probably lateral equivalents.

(3) The Side Harbour formation north of the Long Pond Fault (iv) is intermediate in the stratigraphic sequence. It is underlain by volcaniclastic rocks which apparently pass conformably downward into the core of the Seal Bay anticline, and it is overlain by similar rocks, the thickness of which is uncertain due to folding but which appear to pass upward into the Wild Bight, Badger Bay basalts. The formation may be more or less equivalent to the Glovers Harbour basalts, which appear to lie about 2 km stratigraphically below the Caradocian shale at Leading Tickles and to be separated from it by mainly volcaniclastic rocks. The base of the Glovers Harbour volcanics is not exposed. The Nanny Bag Lake volcanics appear to occupy a similar stratigraphic position as they pass upward through approximately 2 km of volcaniclastic rocks into Caradocian shale east of Nanny Bag Lake.

(4) The relative position of the Long Pond volcanics is not known as they are fault bounded on both the east and west. Likewise, the postion of the Indian Cove volcanics remains somewhat enigmatic as the upper and lower contacts are not exposed. If the western contact is conformable (suggested by the continuity of planar features across the contact area), the Indian Cove volcanics are slightly lower in the section than the Side Harbour formation.

In summary, there is evidence for multiple episodes of volcanic activity during deposition of the Wild Bight Group. The units which contain volcanogenic sulfide mineralization are generally intermediate in the stratigraphic sequence but not necessarily at the same stratigraphic horizon. Detailed structural mapping of the units is needed to clarify these relationships.

(3) Intrusive Rocks

The Wild Bight Group is extensively cut by mafic sills and, less commonly, by dikes ranging from fine grained, locally vesicular diabase to coarse grained, equigranular to somewhat porphyritic gabbro. Fine grained varieties are commonly highly vesicular, locally crosscutting, and some show evidence of intrusion into wet sediments. Most appear to be related to the Wild Bight volcanism and were probably intruded at relatively high levels.

Volcanogenic Sulfide Occurrences

Four principal volcanogenic sulfide occurrences are known in the Wild Bight Group. These were examined in detail on site and, where possible, in drill core. The locations of these deposits are shown on Figure 2 and brief descriptions are presented below.

(1) Point Leamington: This is the largest single massive sulfide deposit known in Newfoundland; it was discovered in the early 1970's by Noranda Exploration Ltd.. Previously published dimensions (Noranda Mines staff, 1974) suggest that more than 20 million tonnes of massive sulfide are present, grading approximately 0.5% Cu and 2% Zn with sporadic precious metal values. The deposit lies at the top of a thick volcanic sequence which is dominantly composed of pillowed basalts (the Side Harbour formation north of the Long Pond Fault, unit iv). In the vicinity of the deposit, the basalts are capped by a 500 m thick unit of felsic quartz-feldspar crystal tuff which has been traced for approximately 1500 m along strike. This unit is the only felsic volcanic member in the Side Harbour formation.

The rocks near the deposit are poorly exposed and the massive sulfide body lies under a bog. A few exposures of highly altered, pyritic, rhyolitic quartz-eye crystal tuff of the footwall outcrop immediately east of the deposit. Similarly altered and mineralized pillow basalt outcrops about 100 m further east. Unaltered volcaniclastic rocks outcrop in the hanging wall to the west of the deposit.

These outcrops summarize the environment; details of the setting are somewhat better displayed in drill core. The massive sulfide body consists mainly of fine grained pyrite with lesser chalcopyrite, and local enrichment of sphalerite as blebs and discrete beds. The contacts of massive sulfides with the hanging wall and the footwall are sharp, although the footwall displays a zone of pervasive alteration recognizable everywhere below the massive body. The alteration consists mainly of variably intense silicification and sericitization commonly accompanied by veinlets, blebs and disseminations of pyrite and lesser chalcopyrite. This pervasive alteration is locally cut by 5 to 30 cm wide crosscutting zones of intense black chlorite alteration which is generally accompanied by more intense sulfide mineralization. In some drill core, the chlorite alteration can be seen to be most intense in the immediate footwall to the massive sulfides and, locally, the lower parts of the massive sulfides have been brecciated, with chlorite introduced between the fragments. The chloritic alteration is believed to represent zones of more intense fluid flow during the alteration/mineralization episode. Where most intensely developed in the immediate footwall, it may record zones of discharge of the mineralizing fluids.

The massive sulfide body has been outlined by diamond drilling to a depth of approximately 260 m, and the nature of the massive sulfides is remarkably uniform from the surface to this depth. The total extent of the body has not yet been determined.

The massive sulfides and the host rocks are cut by numerous mafic dikes ranging from fine grained diabase to coarsely porphyritic gabbro similar to those observed in outcrop throughout the Wild Bight Group.

(2) Lockport: The Lockport deposit was discovered in the late 1870's or 1880's. Early workings on the deposit included a series of open cuts on the gossans which marked the original showings, and five shallow shafts from which a limited amount of ore was apparently shipped to the Tilt Cove smelter near the turn of the century. The property received sporadic attention throughout the early 1900's, but the first comprehensive exploration program did not take place until the 1950's, when NALCO did geological mapping, geochemistry, geophysics and some diamond drilling on the main prospect. Further diamond drilling has been carried out by other firms from the 1960's to the present: 15 holes totalling 2647 m have been drilled on the deposit. The core from these holes has been lost, although drill logs are on file with the Department of Mines and Energy. Grade and tonnage estimates by Fogwill (1965) suggest the presence of approximately 220,000 tonnes of material grading 1.21% Zn and a further 392,350 tonnes grading 0.75% Cu.

The property was the subject of an M.Sc. dissertation at Memorial University by DeZoysa (1969).

The Lockport deposit occurs near the center of the Glovers Harbour volcanics, and is partially exposed in the old open cuts and abundant nearby outcrops. The open cuts expose only the western side of the deposit, although the abundant mineralized material on the adjacent dumps may sample material from the unexposed eastern portion as well. The host rocks exposed in the open cuts comprise mainly intensely sheared, silicified pyroclastic rocks and basaltic flows. Felsic quartz-feldspar crystal tuff outcrops 700 m southwest of the deposit approximately on strike with the mineralized horizon. The mineralization exposed in the open cuts is of stockwork type, characterized by intense quartz-sericite alteration and pervasive disseminations and stringers of pyrite and lesser chalcopyrite. The deposit is highly sheared, and lenses up to 10 cm wide of massive pyrite are present, apparently boudins of what were previously relatively large stringers.

There are no exhalative massive sulfides exposed at the prospect; there are, however, numerous large boulders on the dumps which consist of massive, finely laminated pyrite-chalcopyrite with local concentrations of sphalerite. Logs of holes drilled by NALCO in the 1950's suggest that a massive sulfide zone up to 8 m wide was intersected at the eastern margin of the deposit, and that this zone is characterized by markedly elevated zinc grades (the zinc-rich reserves quoted above). It is possible that this zinc-rich zone represents the exhalative cap to the stockwork zone exposed in outcrop and that this zone was also the source of the massive boulders on the dump. According to the NALCO drill logs, this zone appears to have a strike extent of less than 130 m and to pass into massive pyrite at depth (less than 90 m below surface). The distribution of drill holes is inadequate, however, to delineate the body.

A preliminary interpretation of the relationships at the Lockport deposit, therefore, suggests that it represents a proximal stockwork - massive sulfide system which faces east and is hosted by basaltic flows and pyroclastic rocks of indeterminate original composition. The mineralization may be related to the felsic volcanic episode represented by laterally equivalent crystal tuffs, but this cannot be demonstrated at present.

(3) Indian Cove: The main showing in the Indian Cove volcanics is displayed in a series of outcrops approximately 300 m southwest of Indian Cove. The mineralization is also exposed in several trenches and a small adit. It consists mainly of disseminated and stringer pyrite and chalcopyrite in altered rhyolite and silicic breccia. The mineralized zone is better displayed in drill core from eight holes which were drilled by Texasgulf in 1975. This core is presently stored at the Department of Mines and Energy's core storage library in Pasadena.

The mineralization as seen in core comprises a stockwork zone with a small, central, intensely altered chlorite-pyrite chalcoyrite zone surrounded by less intense sericite-silica alteration containing abundant pyrite-chalcopyrite (sphalerite) stringers. The alteration which accompanies the mineralization is pervasive but uneven in intensity. Quartz-sericite alteration is widely developed and is commonly accompanied by disseminated and stringer pyrite with minor chalcopyrite. Locally, the host rock is almost completely silicified over widths up to 3 m; these zones grade into less altered rhyolite and felsic volcanic breccia in which original textures are preserved. The most intense sulfide mineralization commonly occurs in zones where black chlorite alteration is best developed. These zones are generally 5 to 20 cm wide but locally as wide as 20 m, and generally contain minor amounts of visible sphalerite as well as the ubiquitous pyrite and chalcopyrite. Grades are commonly low. The best mineralization intersected by diamond drilling assayed 1.04% Cu, 0.78% Zn and minor silver over 10 m.

There does not appear to be any truly exhalative mineralization at the Indian Cove prospect. The showing seems to be a particularly intense facies of the pervasive alteration which is present throughout the felsic flow and pyroclastic sequence of the Indian Cove volcanics, and is interpreted as hydrothermal alteration related to the formation of the rhyolite dome at the base of the sequence. The effects of this hydrothermal activity are well displayed at the previously described locality on the shores of Indian Cove; less intense, although ubiquitous, pyritization and sericitization are evident in the felsic volcanic rocks for several hundred metres along strike from the prospect. The alteration at the main prospect is the most intense yet discovered in the sequence and the only one to contain significant quantities of base metals. This may be partly because most exploration on the property has been in the immediate vicinity of the showing. The hydrothermal system, however, is in evidence over an area considerably wider than the showings, and it may well be that zones of base-metal-bearing stockwork as well as exhalative sulfides related to hydrothermal fluid discharge remain to be discovered.

(4) Long Pond: This prospect lies within a narrow belt of rhyolitic tuff and breccia, but is at least in part hosted by a thin basaltic pillow lava / pillow breccia unit which can be traced for several hundred metres along strike. The mineralization consists mainly of heavily disseminated pyrite and minor chalcopyrite; it is accompanied by chlorite-sericite-silica alteration, and is probably stockwork type. No drilling has been recorded from the prospect. This favorable environment deserves a thorough look for massive sulfide mineralization.

Conclusions

This report summarizes the preliminary phase of a project designed to investigate the geological and tectonic environments of volcanogenic sulfide mineralization in Early-Middle Ordovician island-arc sequences of central Newfoundland. Further work in the Wild Bight Group will focus on petrographic, geochemical and isotopic studies of the volcanic rocks and the associated mineralization. Tentative conclusions reached on the basis of field work to date include the following:

(1) The Wild Bight Group records a dominantly volcaniclastic environment, punctuated by brief episodes of volcanic activity. It appears to have been deposited on the middle flanks of a major volcanic edifice located to the south of the presently preserved sequence.

(2) Volcanic accumulations are present at various stratigraphic levels in the sequence. The accumulations display significant differences in lithology and setting. Volcanism was dominantly mafic, but with development of areally restricted felsic domes and possibly ash flows.

(3) Sulfide mineralization accompanied several of the volcanic episodes. Exhalative sulfides are well developed at the Point Leamington deposit and are underlain by stockwork alteration and mineralization. Mineralization exposed on the surface at the Lockport, Indian Cove and Long Pond prospects (and in drill core from Indian Cove) is mainly of stockwork type, although evidence suggests that the Lockport deposit has an exhalative cap which does not outcrop. The potential for the existence of related massive sulfide mineralization is good in all cases.

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H. Scott Swinden

SURFICIAL AND GLACIAL MAPPING OF THE EAST HALF OF THE GREAT GULL POND MAP AREA (12H/1), NEWFOUNDLAND

by

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Introduction

Mapping was conducted in the Great Gull Pond map area during 1983 as a continuation of the Surficial and Glacial Mapping Program in central Newfoundland (Sparkes, 1982). The aim of the project is to provide information on the nature and distribution of surficial landforms, the glacial dispersal of rock materials as an aid to mineral exploration, and to determine the significance of mineralized boulders which were discovered to the west of the mine site. The map area has good road access with numerous till exposures, but only a few bedrock exposures.

Field Program

Field work was started in mid-July and continued until mid-September. Information was obtained along existing roads, lake shorelines and streams as well as from numerous hand-dug and backhoe-dug pits. Three hundred sites were noted and 500 till samples were collected for particle size analyses and geochemistry. A representative pebble fraction (-16mm to +8mm) was obtained at most sites to determine the lithologic composition of the tills). This lithologic study also included geotechnical data such as silt/clay coating, weathering, staining, sphericity, fracturing, mineralogy and texture for each lithology present.

Stratigraphy

Evidence of glacial stratigraphy in the Great Gull Pond map area is limited to several exposures in the vicinity of the former Gullbridge mine. In a pit near the mine site, a 12 m exposure reveals approximately 2 m of a very sandy ablation till with sandy lenses, overlying 2-3 m of a more compact sandy lodgement till with occasional silty lenses. This till overlies up to 8 m of gravel and sand with some interbedded silty sand and silt, which is in turn underlain by striated bedrock which indicates glacial flow in a northeast direction.

Glacial Striae

Striae in the area record two ice flow directions (Figure 1), an early flow towards the northeast (030 to 060), followed by a later flow towards the north (350 to 015). Striae recording the earlier flow are numerous and were observed throughout the area, whereas evidence of the later northerly flow is present on only a few outcrops. The flow directions were assigned to the observed striae using one or more of the following indicators: (a) miniature crag and tail features or 'pressure shadows', (b) crescentic or lunate fractures or gouges, (c) nailhead features, and (d) miniature stoss and lee forms. The relative ages of the striae sets were determined by crosscutting relationships or by leeside preservation of more weathered and degraded striae.

Surficial Deposits and Landforms

Till deposits in the map area range from a thick (>3 m) blanket, possibly of lodgement till, in the area between Crooked Lake and Burnt Pond, to a very thin, discontinuous veneer with numerous rock outcroppings in the area to the north and west of Dawes Pond. An area of extensive ribbed moraine is located in the southwestern corner of the study area and within the South Brook valley. These moraines are generally 3 to 10 m in height, up to 700 m in length, and usually gravelly in texture. They were probably formed in an ice-frontal position and are generally transverse to the direction of ice flow. Linear till ridges, which generally form parallel to the direction of ice flow, are poorly developed within the study area and are limited to the southern part in the area west of Joes Lake.

Conclusions

Glacial dispersion in the Great Gull Pond area may have been affected by two glacial flows, an early northeastward flow and a later northward flow. The lodgement

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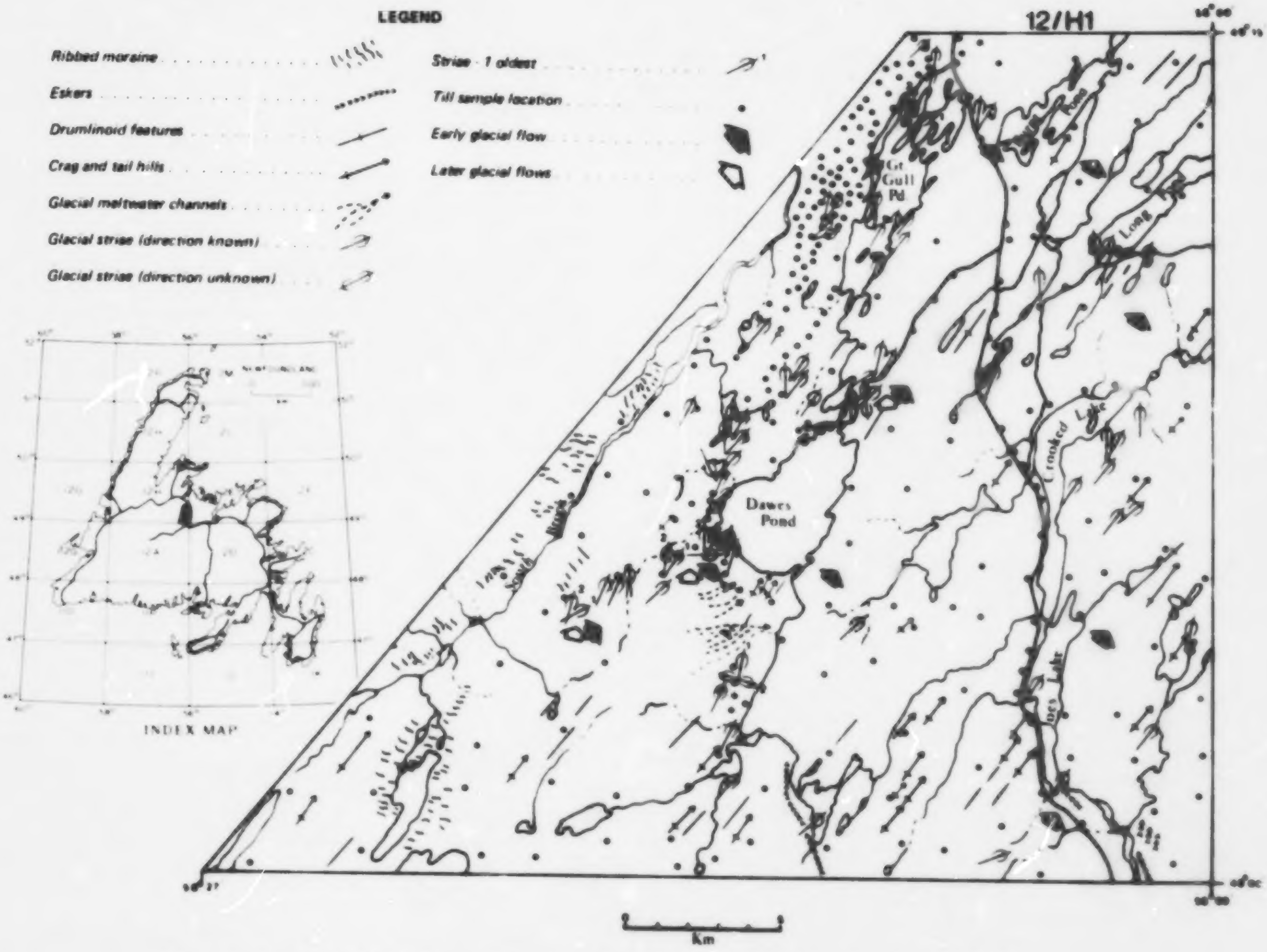
LEGEND
Ribbed moraine
Eskers
Drumlinoid features
Crag and tail hills
Glacial meltwater channels
Glacial striae (direction known)
Glacial striae (direction unknown)
Striae - 1 oldest
Till sample location
Early glacial flow
Later glacial flows
12/H1
Gt Gull Pd
Long
Crooked Lake
Dawes Pond
Km
INDEX MAP

Figure 1: *Surficial geology of Great Gull Pond map area 12H/1.*

till which overlies sand and gravel in the Gullbridge mine area is probably related to the later flow or to a more localized advance of ice in the Great Gull Pond area.

The forthcoming analyses of the pebble fraction of the tills, as well as the particle size and geochemical analyses, should provide more information on the glacial history and distribution and characteristics of the tills of the area.

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B.G. Sparkes

ESTIMATION OF PHYSICAL PARAMETERS OF MacLEAN CHANNEL SULPHIDE-BEARING DEBRIS FLOWS, BUCHANS, NEWFOUNDLAND[1]

W.P. Binney[2]

Binney, W.P., Estimation of physical parameters of MacLean channel sulphide-bearing debris flows, Buchans, Newfoundland; in Current Research, Part A, Geological Survey of Canada, Paper 84-1A.

Abstract

Subaqueous sulphide-bearing debris flows were the major transport mechanism for the ore units in the MacLean channel. Measurement of the coarse blocky detritus in the flow deposits allows estimation of the yield strength of the debris flows. Yield strengths for two debris flows in the MacLean channel were estimated to be 1.0 to 1.5 x 10^3 *N.*m^{-2} *and 3 to 9 x* 10^3 *N.*m^{-2}*. Paleoslopes can be calculated using the estimated yield strength of the debris. Comparisons between calculated paleoslopes (3 and 10°) and actual bedding attitudes (0 to 15°) in the MacLean Extension orebody suggest present bedding attitudes reflect the paleoslope. Data for the sulphide-bearing debris flows are similar to literature values for non-sulphide flows. Uses of the calculations for mineral exploration include basinal analysis and prediction of locations for high grade, dense debris flow deposits at the bases of steep inclines.*

Résumé

Des coulées de débris subaquatiques à sulfures ont été le mécanisme de transport principal des unités minéralisées dans le chenal de MacLean. Le mesurage des débris blocailleux grossiers dans les dépôts permet d'estimer la limite élastique des coulées de débris. Ces limites élastiques sont de 1,0 à 1,5 x 10^3 *Nm*$^{-2}$ *et de 3 à 9 x* 10^3 *Nm*$^{-2}$ *pour deux coulées de débris dans le chenal principal. Il est possible de calculer les paléopentes à partir des limites élastiques estimatives des débris. Une comparaison des paléopentes calculées (3° et 10°) et de la disposition actuelle de la stratification (0° à 15°) dans la masse minéralisée de la prolongation de MacLean permet de croire que la disposition actuelle de la stratification reflète la paléopente. Les données sur les coulées de débris à sulfures sont semblables aux valeurs publiées pour les coulées dépourvues de sulfures. Les utilisations des calculs pour l'exploration minérale comprennent l'analyse des bassins et la prévision des emplacements des dépôts riches de coulées de débris denses accumulés au pied de pentes abruptes.*

INTRODUCTION

In 1982 and 1983 the author investigated the sedimentology of the transported ore in the MacLean channel, Buchans camp, Newfoundland. Shown in plan and section in Figure 1, the orebodies comprise several lithologically distinct beds within a discrete stratigraphic interval. The focus of the work was the MacLean Extension orebody because it is currently being developed and mined. The adjacent MacLean orebody is mined out and most parts are inaccessible.

Individual beds containing sulphide detritus are poorly sorted with angular to subangular lithic and sulphide clasts as long as one metre or more, set in a sand-sized matrix. The base of some beds is inversely graded but most beds have a random internal fabric. The ore-bearing beds have been interpreted as debris flow deposits (Thurlow, 1977; Walker and Barbour, 1981; Calhoun and Hutchinson, 1981; Binney et al., 1983).

Binney et al. (1983) described the distinctive marginal deposits of a typical debris flow observed in the MacLean Extension workings. The contact is at a high angle between the flow centre, with its matrix of sulphides, barite and fine grained lithic detritus, and the margin of the debris flow, with its coarse (greater than 30 cm) blocks of sulphide, granitic and other lithic clasts in a detrital matrix. Such a contact indicates significant matrix strength, and is diagnostic of debris flow margins (Johnson, 1970, p. 434).

Similar debris flow marginal deposits can be observed at several locations in the MacLean Extension workings, thus confirming previous interpretations that at least some of the ore-bearing beds were deposited by debris flows. Although debris flow deposits comprise most fill in the MacLean channel, turbidity current deposits and landslide deposits have also been recognized.

Middleton and Hampton (1976) defined a debris flow as the sluggish downslope movement of mixtures of granular solids, clay minerals and water in response to gravity. Blocks are supported in the flow by the strength of the matrix and deposition occurs when the shear stress applied to the debris drops below its internal strength and the flow 'freezes' in position.

PHYSICAL PARAMETERS

Using the methods of Johnson (1970, p. 486-490) and Hiscott and Middleton (1979), some of the physical parameters of debris flows can be estimated by measurement of coarse, bouldery detritus in the flows. The debris presumably was at a point of critical equilibrium (shear stress equals yield strength) and was just supported when the flow stopped. For these conditions Johnson (1970, p. 461-487) derived an approximate relation between the yield strength (k) of the debris flow and the thickness of a block (c) supported by the flow. Other considerations are the unit weight of the debris flow (γd) and the block (γb) and the depth of penetration of

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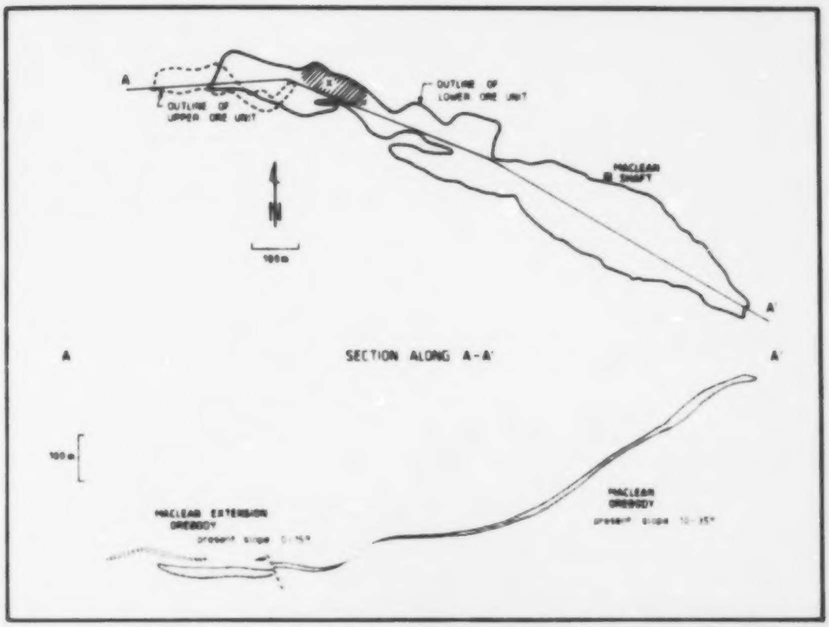

Figure 1

Plan and section of the orebodies of the MacLean channel.

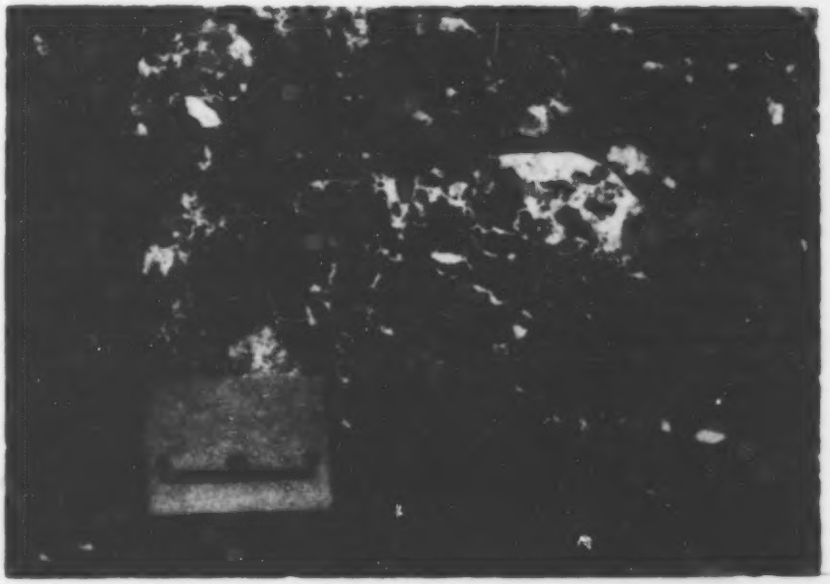

Figure 2

Block of barite-sphalerite-galena completely enclosed by a baritic polylithic breccia-conglomerate bed at the top of the Lower Ore unit, MacLean Extension orebody.

the block into the flow (1/n). The unit weight of a material is the product of its density (kg.m^{-3}) and the acceleration due to gravity (9.80 m.sec^{-2}). The depth of penetration (1/n) is expressed as a fraction, for example if a block is 3/4 submerged in the flow then 1/m = 3/4.

$$k = \frac{c}{4} \left(\gamma b - \frac{\gamma d}{n}\right)$$

The resultant value for the yield strength (k) of the debris flow is expressed in N.m^{-2} where 1 N = 1 kg.m.sec^{-2}. This relationship is particularly amenable to underground exposures where only the thickness and length of individual clasts can be measured. Difficulty arises, however, in assessing the depth of penetration of a block into the debris flow since the upper limit of individual flows cannot everywhere be identified.

To use the relationship, estimates are needed for the unit weight (density times acceleration of gravity) of both the block and the debris flow. The sulphide blocks observed in the debris flow deposits were sufficiently lithified to break with discrete boundaries so their density is estimated from their mineralogical content. Lithic fragments were transported as clasts and their density is assumed to average 2.7 g.cm^{-3}. The density of the debris flow is arbitrarily assumed to be 2.4 g.cm^{-3}, at the dense end of the range of 2.0 to 2.5 g.cm^{-3} reported for subaerial debris flow (Fisher, 1971). This is considered a reasonable assumption as the flows were transporting blocks of density 2.6 to 5.5 g.cm^{-3}. If the density of the flow exceeded that of the blocks there would be a buoyant effect with the lithic clasts floating to the top. This was not observed. The high percentage of sulphide and barite fragments in the deposits does support a high overall density for the debris flows.

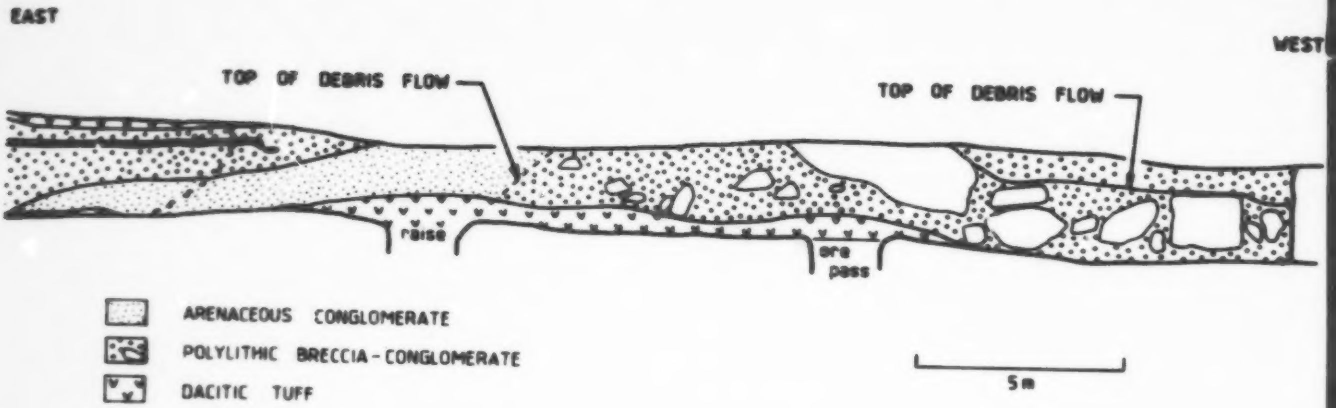

Figure 3. *Section of the Lower Ore unit along a sublevel wall (20-6-1), MacLean Extension orebody. Coarse detritus is observed about the snout of the northward flow. The flow is bounded to the east by arenaceous conglomerate deposited contemporaneously with it but outside of the main body of the flow.*

Individual flows would have different densities but without measurements taken during flow this cannot be quantified with respect to the deposits observed.

The use of Johnson's relationship can be illustrated with reference to a typical debris flow in the MacLean Extension workings. This flow, located at X in Figure 1, occurs at the top of the Lower Ore unit and is laterally extensive, covering an area in excess of 6000 m². Figure 2 illustrates one of the coarser fragments transported by this flow. The thickness of this clast of barite-sphalerite-galena is 0.23 m and it is completely enclosed by the 1.2 m baritic polylithic breccia-conglomerate bed.

$$k = \frac{0.23\ \text{m}}{4}\ ((4.5 - \frac{2.4}{1})(10^3)\text{kg.m}^{-3}(9.80\ \text{m.sec}^{-2})$$

$$= 1.2 \times 10^3\ \text{N.m}^{-2}$$

Other blocks of coarse detritus from this bed gave calculated yield strengths for the debris flow in the range of 1.0 to 1.5 x 10^3 N.m^{-2}.

Another debris flow deposit (Fig. 3) contains coarse blocks of sphalerite-galena and mineralized stockwork up to 4.4 m in length. The debris flow overlies dacitic tuff and forms the base of the Lower Ore unit at this location. Arenaceous conglomerate marginal to the main body of the flow forms the substrate for similar coarse debris flow deposits to the east. The yield strength for the debris flow was calculated using a sphalerite-galena boulder 1.22 m thick and a stockwork boulder 1.52 m thick, 3/4 submerged in the flow. Yield strengths needed to support these boulders are 9 x 10^3 N.m^{-2} and 3 x 10^3 N.m^{-2}, respectively.

Johnson (1970, p. 488) also derived the relationship between the yield strength of the debris in critical equilibrium (k), the slope (δ), the thickness of the flow (Te) and the unit weight of the debris (γd).

$$k = Te\ \gamma d \sin\ \delta$$

This equation was derived using the assumption that the debris flow could be represented as an infinite sheet of plastic material, and is applicable as long as the width of the flow is greatly in excess of its thickness. Knowing the slope, thickness and unit weight of the debris, one can arrive at an independent estimate of the yield strength of the debris. In the case of the MacLean channel, where the amount of postdepositional tilting is unknown, the estimate of yield strength can be used to predict the paleoslope.

For the baritic polylithic breccia-conglomerate which had a yield strength of 1.0 to 1.5 x 10^3 N.m^{-2} based on the maximum clast sizes, the calculated paleoslope is

$$\sin\ \delta = \frac{1.5 \times 10^3\ \text{N.m}^{-2}}{(1.2\ \text{m})(2.4 \times 10^3\text{kg.m}^{-3})(9.80\ \text{m.sec}^{-2})} = 0.053$$

$$\delta = 3°$$

The low slope for this bed is consistent with its position as a late debris flow in the filling of the basin. The calculated paleoslope is within the range of the present dip of the bed of 0 to 8° west.

Calculated paleoslopes for the debris flow illustrated in Figure 3 are approximately 10°, in very close agreement with the actual measured dip of the bed which is 12 to 15°.

These results suggest that the present slopes observed in the MacLean Extension area are a reflection of the paleoslopes that existed at the time of deposition of the sulphide-bearing beds. Due to a lack of access, this comparision of actual and predicted slopes could not be extended into the MacLean workings where the Lower Ore unit has a much steeper dip.

If the present attitudes of the rocks in the MacLean orebody are essentially those of the paleoslope, then the yield strength of the debris flows can be calculated. For the sulphide matrix ore, rich in sphalerite and galena;

$$k = (10\ \text{m})(2.4 \times 10^3\text{kg.m}^{-3})(9.80\ \text{m.sec}^{-2}) \sin 10°$$

$$= 4 \times 10^4\ \text{N.m}^{-2}$$

This result is high compared to the data obtained for debris flows in the MacLean Extension workings. A debris flow with this yield strength could transport boulders in excess of 6 m in diameter. The result indicates one of the limitations of these calculations since no clasts of this size have been recognized in any of the transported orebodies of the Buchans camp. Therefore, the calculated yield strength cannot be confirmed. Sources of error inherent in the calculations are the assumption that sulphide matrix ore was transported by a simple debris flow process and the assumption that the present dip of the bed is identical to the paleoslope.

Using the Hampton number (Hiscott and Middleton, 1979) the velocity (U) that a debris flow would have to exceed for turbulent flow can be calculated. Variables include the strength of the plastic debris flow (k) and the density of the flow (ρd). For turbulent flow;

$$\frac{\rho d\, U^2}{k} \geq 1000$$

For the baritic polylithic breccia-conglomerate bed used throughout this report:

$$U^2 \geq \frac{1000\ (1.5 \times 10^3\ \mathrm{N.m^{-2}})}{2.4 \times 10^3\ \mathrm{kg.m^{-3}}} = 625\ \mathrm{m^2.sec^{-2}}$$

$$U \geq 25\ \mathrm{m.sec^{-1}}$$

Compared with velocity values for subaerial debris flows of 1 to 3 m.sec^{-1} (Sharp and Nobles, 1953; Johnson, 1970, p. 512), this is an unrealistic, high velocity for a flow, especially one depositing coarse unsorted detritus. The result confirms the laminar, nonturbulent nature of flow within the debris flows of the MacLean channel.

SUMMARY AND CONCLUSIONS

The data for yield strength of the sulphide-bearing subaqueous debris flows of the MacLean channel is of the same order of magnitude as that presented by Johnson (1970, p. 490) for subaerial debris flows (1.7 to 5 x 10^3 N.m^{-2}) and Hiscott and Middleton (1979) for subaqueous debris flows in the Tourelle Formation (4 x 10^3 N.m^{-2}). In the MacLean channel the boulders are smaller than in the other studies, but being sulphides, are of much greater density. The variation in yield strength of the flows in the MacLean channel reflects both the diversity of the source area with high density sulphide and lithic detritus to form the flows, and the high local variability of slope in a volcanic environment which has affected the course of the debris flows.

The accuracy of the calculations is subject to the assumptions that Johnson (1970, p. 461-488) made in developing the equations and the fact that a unimodal process of clast support is assumed in applying the equations. Clasts in the MacLean channel have an apparent maximum size based on the author's studies. This may reflect the ability of the debris flows to transport coarse detritus or a limited size range of clasts in the source area.

Even with the limitations outlined, calculations of physical parameters such as debris flow yield strength and paleoslope could be important factors in exploration for sulphide-bearing debris flows such as those at Buchans. Unlike studies of subaerial debris flows, the attitude of preserved subaqueous flows is usually unknown. Even crude estimates of paleoslope may have important implications in basinal analysis and the ultimate success of a mineral exploration program. Changes in paleoslope affect the ability of debris flows with coarse detritus to continue moving downslope. A radical change in paleoslope could result in deposition of debris flows with coarse, high grade sulphide blocks at the base of a steep incline.

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GEOCHEMISTRY OF GRANITOID CLASTS FROM MACLEAN EXTENSION OREBODY, BUCHANS, NEWFOUNDLAND, AND IMPLICATIONS ON THEIR POSSIBLE SOURCE

by

Peter W. Stewart[1]

Abstract

Lithogeochemical analyses have been obtained from samples of the alkali feldspar phase of the Topsails granite, the Feeder Granodiorite and granitoid clasts from ore-horizon breccia-conglomerate beds in MacLean Extension orebody area. The peraluminous Topsails granite is from an A-type (anorogenic) magma which is chemically distinct from the clasts and cannot be their source. The peraluminous Feeder Granodiorite and granitoid clasts are both from I-type (orogenic) magmas and have many geochemical similarities and some differences. The Feeder Granodiorite may be a late-stage differentiate of the magmatic source of the clasts. Variable alteration of the clasts complicates lithogeochemical interpretations. A revised petrographic classification of clasts is presented.

Introduction

The volcanogenic sulfide ore deposits at Buchans occur as three types, stockwork ore, *in situ* ore and transported ore (Thurlow, 1981a; Thurlow and Swanson, 1981). These deposits are hosted by the Buchans Group of the Newfoundland Central Volcanic Belt (Kean et al., 1981), an Ordovician-Silurian sequence of subaqueous volcanic, volcaniclastic and sedimentary rocks.

The transported ore forms a series of sulfide-bearing breccia-conglomerate beds with diverse lithic clasts, including granitoids. These beds have been interpreted as the deposits of debris flows (Walker and Barbour, 1981; Binney et al., 1983).

The source of the granitoid clasts has been enigmatic. Two small intrusive bodies (Wiley's River and Little Sandy intrusions) have been interpreted to be comagmatic with the Buchans Group volcanic rocks and possible sources of the granitoid clasts. They have been collectively named the Feeder Granodiorite (Thurlow, 1981a,b).

Major and trace element analyses have been determined for 21 clasts collected from 20 Level of the MacLean Extension workings. Eight samples of the Wiley's River intrusion and one sample of the Little Sandy intrusion were analyzed for the same elements. Also, seven samples of the alkali feldspar phase of the Topsails granitic complex (Taylor et al., 1980; Thurlow, 1981b) from adjacent to the Buchans Group and the Wiley's Brook intrusion were analyzed for comparison.

Petrography

Thin sections of more than 150 granitoid clasts from ore horizon boulder breccia beds have been examined. More than 90 per cent of these were from MacLean Extension orebody, with the remainder from the Oriental orebody. A petrographic classification of granitoid types is presented in Table 1 and is considered more useful than the field classification proposed by Stewart (1983); the field clast groupings of Stewart (1983) lacked geochemical coherence or petrographic distinctiveness.

Primary mineralogy of the clasts is simple and relatively consistent, i.e. quartz, plagioclase, biotite (rarely preserved, now chlorite), opaque minerals (hematite, magnetite?), apatite, zircon and sphene (rare).

Detailed petrographic examination of clasts has demonstrated that color and mineralogical differences used in the earlier classification are primarily due to alteration. Textural differences are gradational and probably represent differences in the mode and timing of crystallization of a single magma. The clast types have been arranged to reflect these gradations, from those with the best developed crystallinity (Type 1) to the least developed (Type 5).

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Table 1: *Petrographic classification of granitoid clasts.*

Clast type	Grain size (mm) (average/range)	Texture	Phenocrysts	Mafic mineral content	Distinguishing features
1	medium (1 / 0.2-3.0)	seriate porphyritic	abundant qtz + feldspar; qtz typically larger (to 5 mm)	rare biotite; mostly chlorite + opaques after biotite ± epidote (5%)	relatively coarse grained seriate texture, i.e. gradation in grain size of groundmass to phenocrysts
2	fine (0.5 / 0.1-2)	relatively equigranular	qtz + feldspar (to 2 mm)	rare biotite; mostly chlorite + opaques after biotite + epidote (0-5 vol. %)	relatively intermediate grain size and equigranular
3	fine to very fine (0.3 / 0.1-0.5)	hiatal porphyritic - rare micro-granophyric areas	qtz + feldspar (1-8 mm) in clusters (especially feldspars)	chlorite + opaques ± epidote (5%)	hiatal porphyritic - large difference in size between phenocrysts and groundmass; abundant phenocrysts
4	very fine (0.2 / 0.1-0.4)	equigranular	rare qtz + feldspar (to 2 mm)	chlorite + opaques ± epidote zoisite (5%)	equigranular, fine grain size, lack of phenocrysts relatively minor micro-granophyric areas
5	very fine to fine (0.5 / 0.1-2)	variable % of well developed micrograno-phyric patches	rare, mostly qtz (to 2 mm)	chlorite + opaques ± epidote (0-5%)	abundant micrographophyre; equigranular
6	very fine (0.2 / 0.1-0.4)	equigranular euhedral to subhedral feldspars	none	very abundant, especially opaques, biotite and chlorite (to 10%)	'lath-like' texture of feldspars; abundant mafic minerals - almost exclusively restricted to siltstone breccia, under ore horizon

Type 6 clasts are texturally and mineralogically distinct. They show a weakly developed felty texture with euhedral to subhedral plagioclase laths in a groundmass of anhedral plagioclase, quartz and opaque minerals. These clasts show a higher plagioclase/quartz ratio and a higher per cent of mafic and opaque minerals than the other clast types. This type is also chemically distinct (lower SiO_2, higher TiO_2 and CaO) and primarily restricted to the siltstone breccia unit which occurs several metres stratigraphically beneath the lower ore unit in the MacLean Extension area. However, rare clasts of this type have been found within the lower ore unit.

Staining with sodium cobaltinitrite for potassium feldspars suggests that all feldspars are plagioclase. The alteration and lack of twinning of feldspars have prevented petrographic determination of An content, but the major element geochemistry suggests that they are predominantly of albitic composition.

The dusty and pitted appearance of the feldspars and the presence of secondary minerals (sericite, calcite, epidote) in the feldspar crystals suggest that they have been saussuritized. Whether this is due to hydrothermal alteration or is a product of regional metamorphism is not known. The regional metamorphism of the Buchans Group is of the prehnite-pumpellyite facies (Henley and Thornley, 1981), and the alteration may have been a product of this metamorphism.

Geochemistry

The study was designed to assess the relationship among three sample populations: the granitoid clasts, Feeder Granodiorite (FG) (predominantly the Wiley's River intrusion), and Topsails granite. The present geochemical results are preliminary, but do suggest several points: (1) all rock types are silica-oversaturated and peraluminous; (2) the FG and the clasts are from I-type (orogenic) magmas, whereas the Topsails granite is from an A-type (anorogenic) magma; (3) trace element abundances show significant differences between the Topsails granite and the other two populations; (4) the magmatic relationship of the FG and the granitoid clasts cannot be conclusively established, or refuted with the present evidence; and (5) the clasts have undergone varying degrees of alteration, whereas the FG and the Topsails granite are comparatively unaltered. These points are examined in more detail below.

All clast samples were found to contain greater than 70% (wt.%) SiO_2 (anhydrous) with some clasts exceeding 80% SiO_2. Both the FG and the Topsails granite have a more restricted silica range of about 5% SiO_2, all above 70% SiO_2.

Because of the mobility of the alkali elements during alteration, their usefulness for classification of altered rocks is suspect. As will be discussed below, the alkali distributions in the clasts were affected by alteration. For this reason, plots after Irvine and Baragar (1971) and AFM plots are not presented; however, they suggest a calc-alkaline affinity for all populations. Strong (1977) and Thurlow (1981a) demonstrated that the Buchans Group is calc-alkaline.

Using the granitoid classification scheme of White and Chappell (1983), the granitoid clasts and the Feeder Granodiorite crystallized from I-type magmas and the Topsails granite from an A-type magma (Figure 1). Figure 1b is probably a more reliable plot that Figure 1a which uses alkali elements. The elements Ga and especially Al are considered to be relatively immobile during alteration, unlike the alkali elements. High contents of highly charged cations such as Ga, Zr and Y (see Figures 1b and 2) are considered diagnostic of A-type magmas (White and Chappell, 1983). A-type granitoid bodies in eastern Australia are associated in space and time with volcanic rocks, as is the Topsails granite (Whalen and Currie, 1983). The presence of miarolitic and granophyric textures further substantiates the designation of the Topsails granite as an A-type intrusion (White and Chappell, 1983, page 30).

Although I-type magmas are usually subaluminous, the Feeder Granodiorite and granitoid clasts are peraluminous. This may indicate a minimum-temperature melt or a highly fractionated I-type melt (White and Chappell, 1983, page 28). This allows the possibility that FG is the more fractionated parent of the granitoid clasts, but this has not yet been demonstrated.

Plots of paired immobile elements (Figure 2) have been shown to be effective in distinguishing different magma series and their tectonic settings (Pearce and Cann, 1973; Wood et al., 1979; Palacios et al., 1983). The distinctiveness of the Topsails granite is obvious while the correlation between the clasts and the FG is suggested. Bailey (1981) proposed that Zr and Y enrichment distinguishes anorogenic andesites from orogenic andesites, which supports the anorogenic setting of the Topsails granite. The slight enrichment of the FG in Zr and Y relative to the clasts is suggestive of a late stage differentiate (Taylor, 1965).

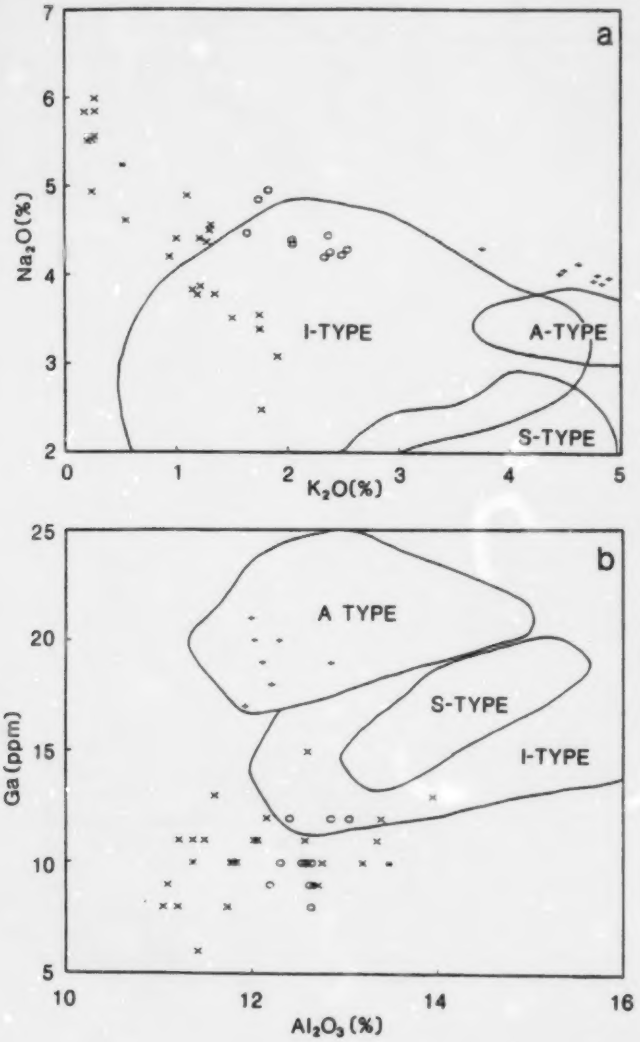

Figure 1: *Discriminant diagrams for granitoid magma series from White and Chappell (1983): (a)* K_2O *vs.* Na_2O*; (b)* Al_2O_3 *vs. Ga. The 'x' represents a granitoid clast sample from MacLean Extension orebody, 'o' represents a Feeder Granodiorite sample, the '+' represents a Topsail (alkali feldspar) granite sample, and the '*' represents the sample from the Little Sandy Intrusion.*

Alteration

The most common expression of hydrothermal alteration is the production of hydrous minerals from the primary anhydrous minerals. Therefore, the loss on ignition (LOI) provides a qualitative means to judge the degree of alteration. Although the LOI may be a mixture of H_2O, CO_2 and sulfur-bearing gases, for evaluation of the degree of alteration, LOI is considered to be mainly H_2O and CO_2.

The variable degree of alteration of the clasts is apparent in Figure 3. A positive correlation between both CaO and K_2O with loss on ignition is shown in Figures 3b and c. The feldspars are partly altered to sericite (or muscovite) and calcite, indicating that these chemical variations probably reflect alteration. The very high barium content of the clasts in general, and the presence of barite as secondary veins and disseminations in the clasts is also in accord with the weakly defined positive correlation between Ba and LOI in Figure 3d. Magnesium values scatter around a weak positive correlation (Figure 3a). Variable amounts of chlorite and magnesium in the clasts could indicate an alteration, rather than a metamorphic origin for the chlorite. Alteration is indicated mineralogically by the saussuritization of feldspars, chloritization of biotite (no other primary mafic mineral, or relicts of other mafic minerals have been recognized) and introduction of barium and calcium as barite and calcite. The elevated Ba values in the clasts probably indicate that their alteration is related to the mineralizing event at Buchans (Thurlow, 1981a) or to migration of Ba from barite in the breccia-conglomerate beds during or after consolidation (*op. cit.*, page 285). The presence of calcite ± barite veins in some samples analyzed could add to LOI scatter and mask the chemical effects of rock alteration.

Ca and Sr are considered to behave similarly under many conditions (Taylor, 1965; Mason, 1966). This behavior and the contrasting dissimilar behavior of Rb and Sr are demonstrated in Figure 4. Sr content shows a corresponding increase with Ca content (Figure 4b), whereas Rb and Sr has a negative correlation (Figure 4a). The increase of Ca and Sr contents in the clasts is believed due to the introduction of calcite during alteration. Rubidium contents remain relatively constant in the clasts though Sr values increase. Unless Rb was uniformly depleted, which conflicts with the generally variable nature of the alteration, it was apparently unaffected by the alteration.

Figure 5 presents evidence which possibly conflicts with FG being the parent of the clasts. If it were the parent, then it should have had a similar K_2O content, prior to the alteration of the clasts. If, as is indicated in Figure 3c, K_2O increased with degree of alteration (along with

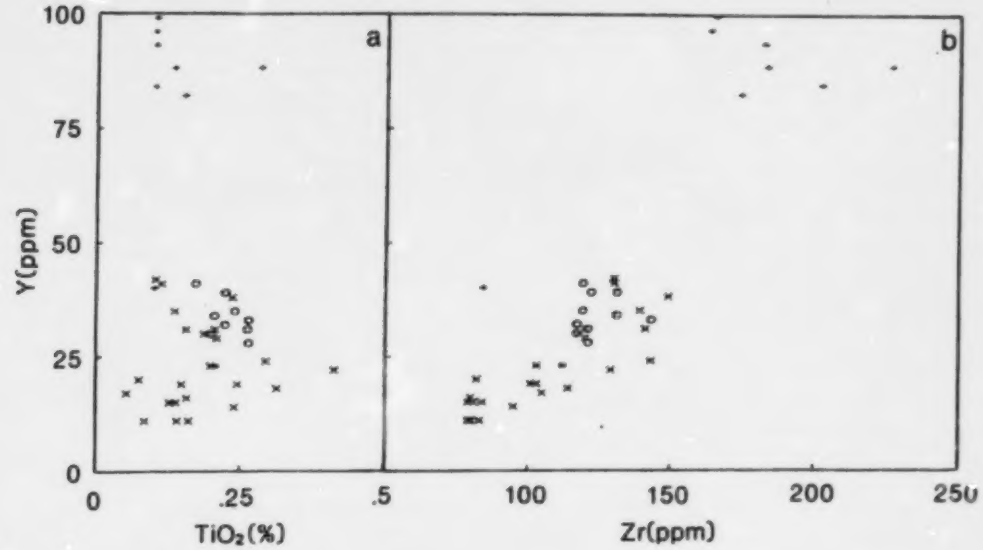

Figure 2: *Plots of relatively immobile elements: (a) TiO_2 vs. Y; (b) Zr vs. Y; after Palacios et al., 1983. For symbols see Figure 1.*

increasing Sr (Figure 4)) then the clasts in Figure 5 should plot toward the upper left part of the diagram and not the lower left part as indicated. Even if the FG is a later differentiate of the same magma and has a higher initial K_2O content, the observed trend still cannot be resolved. This underlies the difficulities in determining the changes in element contents during alteration. Work is in progress to try to resolve this problem.

The lack of apparent alteration of the FG and the Topsails granite is obvious from Figures 3 and 4. The fields for the Topsails alkali feldspar phase and the FG of Bell and Blenkinsop (1981) are shown in Figure 4a for comparison.

One of the samples designated as a Topsails granite plots consistently outside the cluster of other Topsail samples. This is a sample of a dike which closely resembles the Topsails granite megascopically. The trace element chemistry suggests that it was possibly modified by contamination from the FG during emplacement (see Figure 2a and b, especially).

The single data point for the Little Sandy intrusion is insufficient to permit any rigorous conclusions. The data do suggest, however, a closer affinity to the clasts than to the FG itself. Further analyses of samples from this body are currently in progress.

Conclusions

A few preliminary conclusions can be drawn. The Topsails granite can be clearly separated petrographically and lithochemically from the Feeder Granodiorite and granitoid clasts. This is consistent with the established geological and age relationships for the Topsails granite (Thurlow, 1981b; Bell and Blenkinsop, 1981; Whalen and Currie, 1982 and 1983). As first demonstrated by Thurlow (1981a), the FG has many geochemical similarities to the clasts and may have crystallized from the same magma reservoir which produced the clasts. Other element combinations suggest that the FG and clasts are geochemically distinct and not genetically related. Further work remains to be done before this problem can be resolved.

The FG and Topsails granite are both unaltered to weakly altered, whereas the clasts are variably altered. K_2O, CaO, MgO, Ba and Sr contents of the clasts increase erratically with increasing alteration.

Acknowledgements

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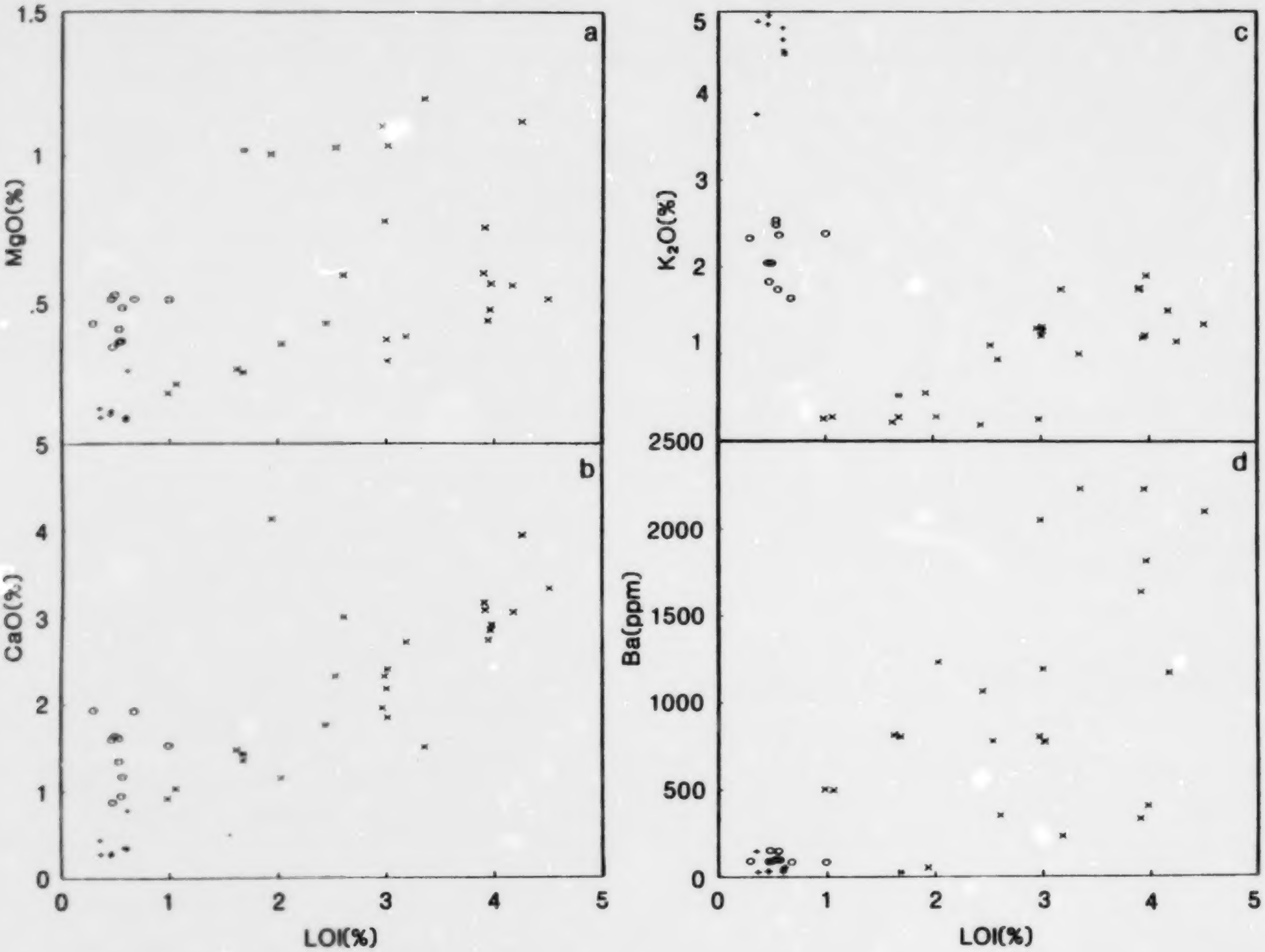

Figure 3: *Diagrams illustrating the effects of alteration on particular elements:* ***(a)*** *loss on ignition (LOI) vs. MgO;* ***(b)*** *LOI vs. CaO;* ***(c)*** *LOI vs. K_2O;* ***(d)*** *LOI vs. Ba. For symbols see Figure 1.*

This study comprises a portion of the work towards a Master of Science degree at Memorial University.

Critical reviews of this report by R.V. Kirkham, W.H. Poole, D.F. Strong and J.G. Thurlow resulted in numerous improvements.

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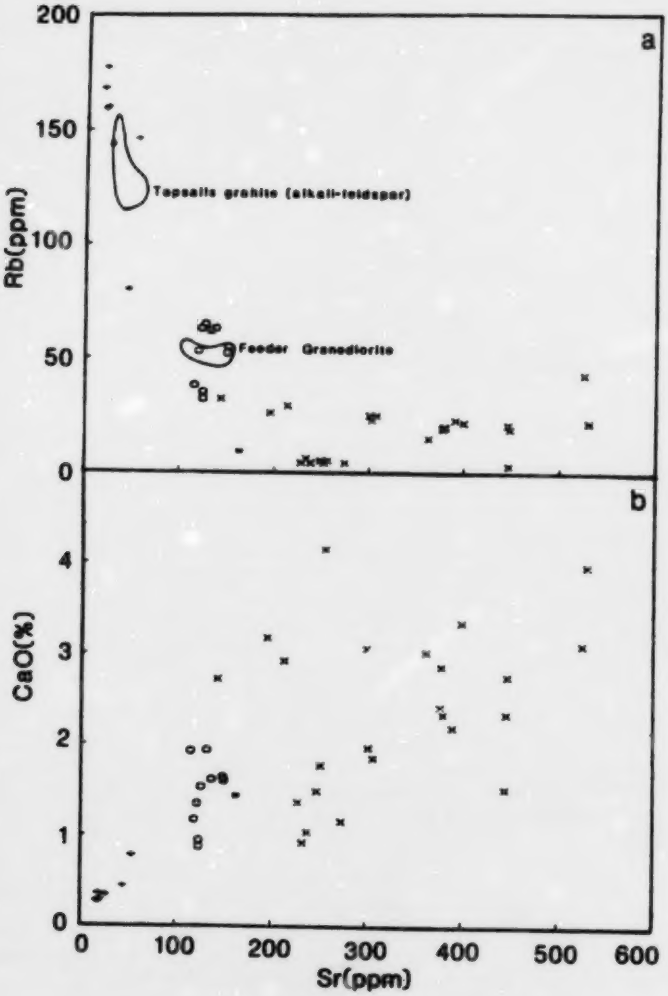

Figure 4: *Correlation diagrams: (a) Sr vs. Rb, fields after Bell and Blenkinsop, 1981; (b) Sr vs. CaO. For symbols see Figure 1.*

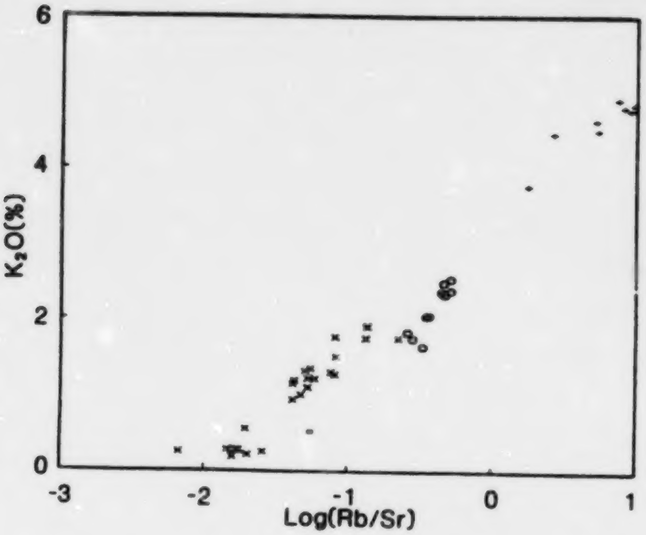

Figure 5: *Rb/Sr expressed logarithmically vs. K_2O. For symbols see Figure 1.*

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BUCHANS, NEWFOUNDLAND: A CASE STUDY OF RARE EARTH ELEMENT PATTERNS

by

D.F. Strong[1]

Introduction

In recent years, there has been a rapid increase in the application of rare earth elements (REE) to the study of mineral deposits, and there are indications that such studies may have applications in mineral exploration. Taylor and Fryer (1983) recently completed a comprehensive review of such studies on granophile deposits. Thurston (1980, 1981) was the first to recognize that Archean felsic volcanic rocks of the Canadian Shield which host massive sulfide deposits are characterized by 'flat' REE patterns, while associated nonmineralized units have steeper negative-sloping REE patterns. Campbell et al. (1981, 1982) confirmed these observations, and the patterns discussed by them are summarized in Figure 1. The very high grade polymetallic sulfide deposits in Ordovician-Silurian volcanic rocks at Buchans, Newfoundland provide an ideal opportunity to test the applicability of the findings from the Archean volcanic rocks.

Geological Setting

A comprehensive description of the geological setting and the mining history of the Buchans deposits was published in 1981 as a special paper of the Geological Association of Canada (Swanson et al., 1981). Some revisions to the details of the geological setting have resulted from recent work, for example, by Binney (1984).

Production at Buchans started in 1928. Just over 16 million tonnes of ore had been mined to the end of 1983. The orebodies have been spectacularly high grade, averaging 14.62% Zn, 7.60% Pb, 1.34% Cu, 226.5 g/t Ag, and 1.474 g/t Au (Thurlow and Swanson, 1981).

Thurlow et al. (1975) first described these polymetallic deposits as similar to the volcanogenic Kuroko-type of Japan. The recognition of thrust faults within the volcanic sequence has resulted in a revision of the stratigraphy described by Thurlow, as shown in Figure 2 and described in Table 1. The samples used in this study were taken from Thurlow's original collection, but they have been reassigned to the stratigraphic units shown in Figure 2.

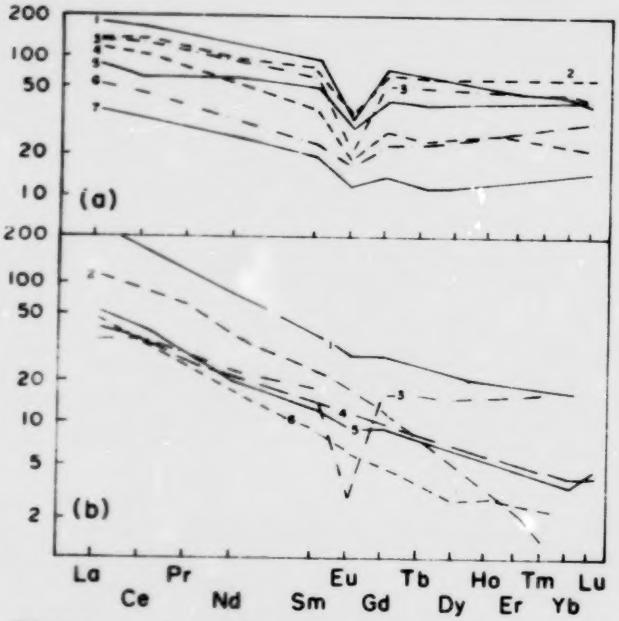

Figure 1: *Chondrite-normalized REE patterns for seven ore-bearing (a) and six barren (b) felsic volcanic rocks given by Campbell et al. (1982).*

Analytical Methods

Fifty-seven samples were selected from a collection of rock powders which were chemically analyzed by Thurlow (1980); the full chemical data are given by him. Samples were chosen representing each of the stratigraphic units in the volcanic sequences which host the Buchans orebodies, and some dike samples were included to represent possible late-stage magmatism.

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The REE concentrations were determined at Memorial University (MUN) using the thin-film X-ray fluorescence technique of Fryer (1977), the same method used by Thurston (1980, 1981) and subsequently supported by Campbell et al. (1981, 1982) using instrumental neutron activation analysis. The data are available from the author on request. Sample number JGT-160B, a rhyolite flow from the Skidder area, was analyzed with three separate analytical batches. These duplicate analyses provide an indication of the precision (Figure 3a) which agrees with numerous estimates of precision and accuracy at ± 15% or better made during routine analysis at MUN (B.J. Fryer, personal communication and manuscript in preparation). The REE patterns plotted in Figures 3 and 4 are normalized to the chondrite values given by Taylor and Gorton (1977).

Rare Earth Element Data

The samples are grouped into 'felsic' and 'mafic' types, but there are 'intermediate' compositions which may fall into either group. To facilitate comparison, the SiO_2 concentrations are written on the summary diagrams, along with concentrations of Na_2O, K_2O, LOI, and Ba. These components give some indication of the degree of alteration. The REE patterns are sequentially arranged in Figures 3 and 4 with the stratigraphically lowest units at the top. The following discussion proceeds from oldest to youngest.

Felsic Rocks

Figure 3a shows that felsic rocks from the lowest units, the Footwall dacite and the Skidder rhyolite, have relatively flat

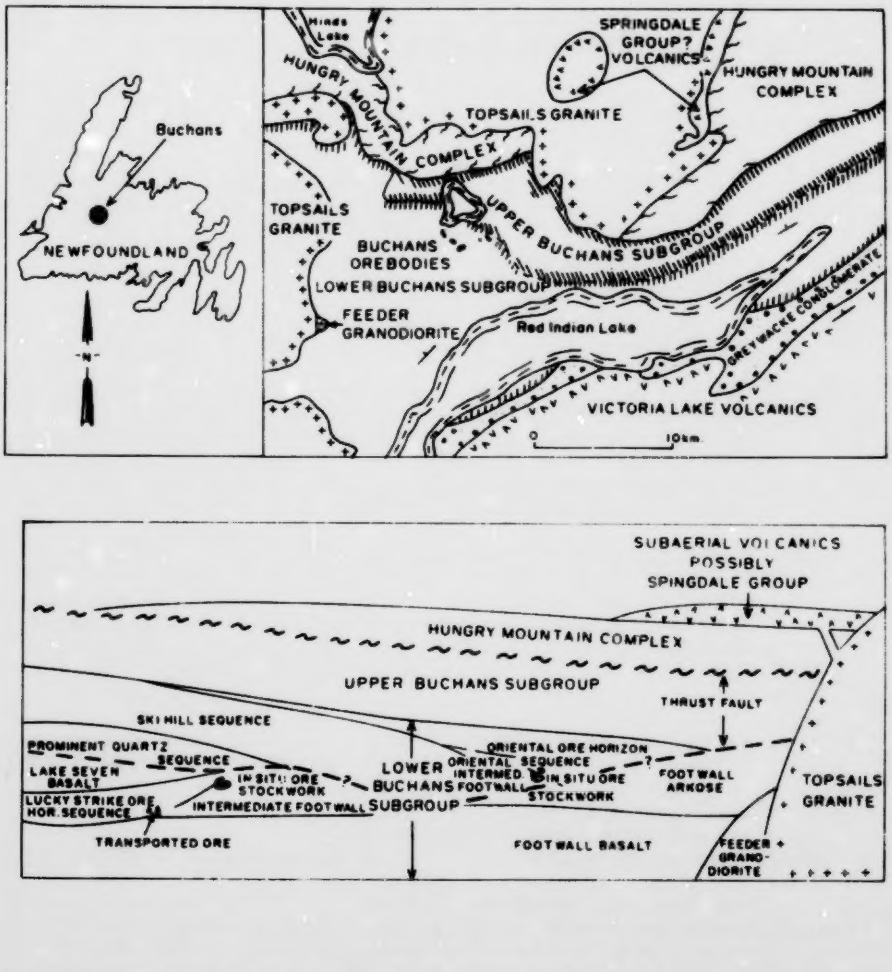
Buchans
NEWFOUNDLAND
-N-
Hinds Lake
HUNGRY MOUNTAIN COMPLEX
SPRINGDALE GROUP? VOLCANICS
HUNGRY MOUNTAIN COMPLEX
TOPSAILS GRANITE
TOPSAILS GRANITE
UPPER BUCHANS SUBGROUP
BUCHANS OREBODIES
LOWER BUCHANS SUBGROUP
FEEDER GRANODIORITE
Red Indian Lake
GREYWACKE CONGLOMERATE
VICTORIA LAKE VOLCANICS
0
10km
SUBAERIAL VOLCANICS POSSIBLY SPINGDALE GROUP
HUNGRY MOUNTAIN COMPLEX
UPPER BUCHANS SUBGROUP
THRUST FAULT
SKI HILL SEQUENCE
PROMINENT QUARTZ SEQUENCE
ORIENTAL ORE HORIZON
ORIENTAL SEQUENCE
LAKE SEVEN BASALT
IN SITU ORE STOCKWORK
LOWER BUCHANS SUBGROUP
INTERMED. FOOTWALL
IN SITU ORE STOCKWORK
FOOTWALL ARKOSE
TOPSAILS GRANITE
LUCKY STRIKE ORE HOR. SEQUENCE
INTERMEDIATE FOOTWALL
TRANSPORTED ORE
FOOTWALL BASALT
FEEDER GRANO-DIORITE

Figure 2: *Simplified geological map (a) and schematic stratigraphy (b) of the Buchans area (after Thurlow and Swanson, 1981). See Table 1 for lithological descriptions.*

TABLE 1: STRATIGRAPHY OF THE BUCHANS GROUP*

Unit (Maximum thickness)	Lithologies	Mineralization
Upper Buchans Subgroup (2000 m (?))	Mafic to felsic pyroclastics and breccias with lesser flows, minor volcanic sediment. Includes a basal member (Upper Arkose) of resedimented conglomerate.	Little Sandy Prospect (Cu) and several areas of weakly to heavily disseminated pyrite, and traces of chalcopyrite.
Lower Buchans Subgroup		
Oriental Ore Horizon Sequence (400 m)	Dacitic tuff, rhyolite breccia domes, pyritic siltstone and wacke, pyroclastic breccia, polyvolcanic breccia-conglomerate, "granite conglomerate".	High grade massive sulfide orebodies: Oriental #1 and #2. Old Buchans Conglomerate and possibly Old Buchans East and West. Sandfill and Middle Branch Prospects.
Oriental Intermediate Sequence (300 m)	Pumiceous felsic pyroclastics and pyroclastic breccias, local altered intermediate and mafic flows, pyroclastics and breccias.	Minor ore grade stockwork mineralization with larger areas of subeconomic epigenetic Pb-Zn-Cu.
Ski Hill Sequence (1000 m)	Mainly andesitic pyroclastics and breccias; minor basaltic flows, dacitic tuff.	Local isolated black ore clasts.
Prominent Quartz Sequence (2000 m)	Mainly dacitic pyroclastics, pyroclastic breccias and related tuffaceous sediments, lesser rhyolite. Interbedded basaltic and andesitic units, jasper chert.	Local disseminated pyrite, Pb-Zn and traces of Pb-Zn veining.
Lake Seven Basalt (350 m)	Basaltic pillow lava, pillow breccia and lesser pyroclastics.	Barren.
Lucky Strike Ore Horizon Sequence (600 m)	Dacitic tuff, massive rhyolite, pyritic siltstone and wacke, pyroclastic breccia, polylithic volcanic breccia-conglomerate, "granitic conglomerate", local basaltic and andesitic horizons.	High grade massive sulfide orebodies: Lucky Strike, North, Two Level, Rothermere #1 and #2, MacLean, Clementine Prospect. Subeconomic trains and isolated occurrences of sulfide clasts.
Intermediate Footwall (250 m)	Complexly interbedded and altered mafic to felsic flows, pyroclastics and breccias, related tuffaceous pyritic siltstone and wacke.	Localized ore grade pyritic stockwork Zn-Pb-Cu mineralization. Small, stratiform, high grade, polymetallic massive sulfides. Larger areas of subeconomic disseminated and veinlet mineralization.
Footwall Arkose (2500 m)	Mainly lithic arkose; lesser arkosic conglomerate, siliceous graywacke; minor siltstone, mudstone, chert. Contains felsic pyroclastics several kilometres east of Buchans.	Connel Option: very small bedded pyritic Pb-Zn occurrence; otherwise barren.
Footwall Basalt (2000 m (?))	Basaltic pillow lava, pillow breccia, lesser pyroclastics, massive flows, interbedded chert. Very minor felsic pyroclastics.	Skidder Brook pyritic massive sulfide deposit (Cu-Zn).

* After Thurlow and Swanson (1981)

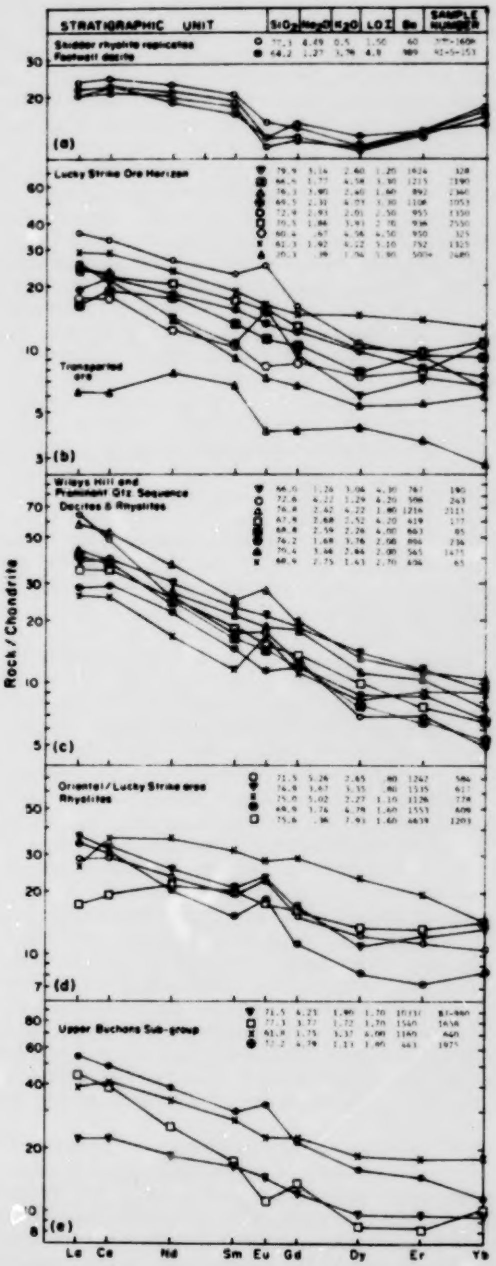

Figure 3: *Rare earth element patterns, normalized to chondrite data given by Taylor and Gorton (1977), for 'felsic' volcanic rocks of the Buchans area. Additional chemical data are given in weight percent. In Figure 3(c), samples 85, 234, 1475 and 65 are from the Prominent Quartz Sequence.*

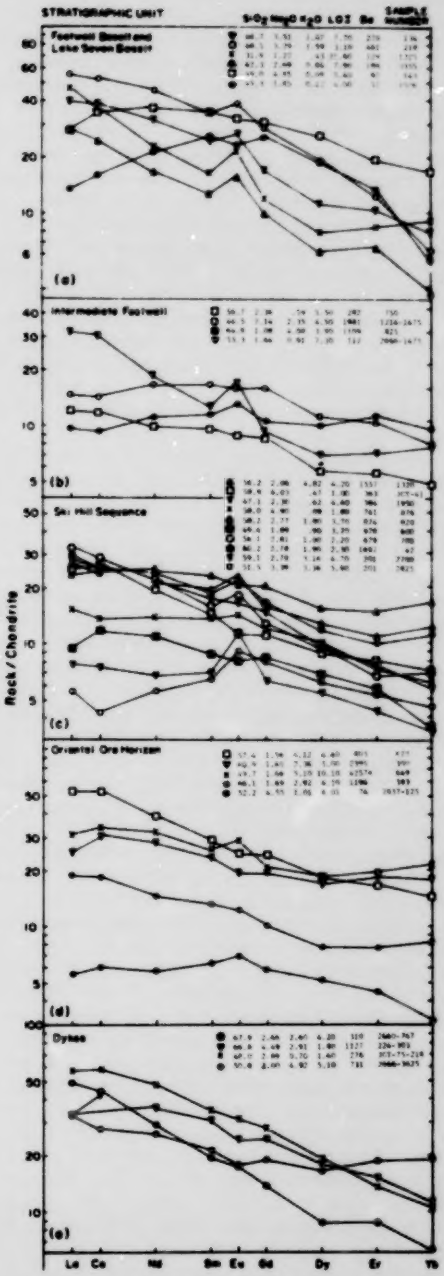

Figure 4: *Rare earth patterns for the 'mafic' volcanic rocks of the Buchans area. In Figure 4(a), samples 143 and 1526 are from the Lake Seven Basalt.*

patterns with a slight depletion of Eu and enrichment of Er and Yb. There is no significant difference between the rhyolite and the dacite REE patterns, despite their differences in most other elements, and their apparent differences in alteration, as indicated by variations in LOI, Na/K, etc.. The flat patterns are comparable to those shown in Figure 1 for Archean mineralized rocks at Golden Grove, Western Australia (sample 6), and the mid-Miocene Kuroko district of Japan (sample 7), although the absolute abundances as shown by the chondrite ratios (indicated henceforth by *) of the latter are much higher. This similarity is noteworthy in that the Footwall sequences are shown by Thurlow (1980, *his Figure 3-1)* to form only a basement to the mineralized volcanic sequences, and not to have significant mineralization themselves (Figure 2).

REE patterns for silicic volcanic rocks from the Lucky Strike and Oriental ore horizons are shown in Figures 3b and 3d. The patterns for the two horizons are similar, but the total REE concentrations (TREE*) are generally lower in the Lucky Strike horizon. All have generally negative slopes, although not as steep as those for the unmineralized samples shown in Figure 3c. Also, they show a slight enrichment of Yb* (i.e. higher Yb/Gd*) relative to the patterns in Figure 3c. Likewise, the TREE* concentrations are generally lower, with La* less than 35 and Yb* less than 15. The only ore sample analyzed in this study, number 2480 (transported ore, Figure 3b), shows much lower TREE*, similar to that determined by Graf (1977) for massive sulfides in the Bathurst, New Brunswick area. There are no significant Eu* depletion anomalies in these mineralized samples, although there are several positive Eu* anomalies. These do not correspond to any obvious indication of feldspar enrichment, either through albitization (higher Na_2O) or plagioclase accumulation (higher CaO or Na_2O), although plagioclase phenocrysts are common in most of the Buchans volcanic rocks. Likewise, the TREE* are not enriched, providing no evidence for significant differentiation of the magmas from which they were derived.

Figure 3c shows the REE patterns from two units apparently unrelated to ore, i.e. the Wileys Hill Sequence at some distance from and stratigraphically lower than ore, and its possible stratigraphic equivalent, the Prominent Quartz Sequence. There is no significant difference between the two groups, both showing slight positive Eu* anomalies like those in the mineralized units, and slightly more negative slopes, with La* between 65 and 26, and Yb* between 9.36 and 4.92. One exception is sample 65, dacitic tuff from the Prominent Quartz Sequence, which shows a flatter pattern than the others. There is no obvious indication from the other elements that alteration might explain this difference and there is no correlation between alteration and REE patterns of the other rocks. These patterns conform to what would be expected for unmineralized Archean volcanics (Figure 1), i.e. calc-alkaline REE patterns with negative slopes, although the TREE* of the Buchans rocks are significantly lower.

Similar negative slopes are observed for two of the felsic volcanic rocks of the Upper Buchans Subgroup (Figure 3e), but there is a slight relative enrichment of the HREE (higher Yb/Gd*) in three samples. These rocks also have higher average Ba concentrations than those of Figure 3c, although the Upper Buchans Subgroup is shown by Thurlow (1980, *his Figure 3-1)* to overlie the mineralization (Figure 2).

Mafic Rocks

REE patterns for the Footwall Basalts and Lake Seven Basalts, both unmineralized, are shown in Figure 4a. The former have generally negative slopes which are unaffected by alteration. Sample 1225, which contains more than 20% CO_2 (and 27.4% CaO), differs from the others only by a slight enrichment in Er and Yb, as would be expected from the effects of CO_3-complexes as agents of HREE transport and deposition (Taylor and Fryer, 1983). Samples 143 and 1526, from below the Prominent Quartz Sequence, show flatter patterns with lower LREE* and higher HREE* than the Footwall Basalts. This may reflect a loss of LREE from originally similar rocks, e.g. by feldspar fractionation, but there is no Eu-enrichment anomaly to support such a suggestion. Instead, the difference may be an original magmatic feature, i.e. these rocks may be genetically different, possibly somewhat fractionated tholeiites instead of calc-alkaline basalts. However, it is equally possible that the LREE were lost during greenschist facies alteration.

REE patterns for unmineralized mafic fragmental rocks from the Intermediate Footwall and the Prominent Quartz Sequence are shown in Figure 4b. Except for sample 2666-1475 from the Prominent Quartz Sequence, the patterns have substantially lower LREE* values than those of the Footwall Basalts but their HREE* are similar. The two samples with lowest TREE* have contrasting K_2O and Ba, and both are more siliceous than the other samples.

Unmineralized mafic rocks from the Ski Hill Sequence are also different from most of the Footwall Basalts, having higher silica and Ba concentrations; most can be described as andesites. They also have different TREE*, generally with La* below 33 compared to values above 40 in the former, but they are like the Footwall Basalts in having slightly positive to insignificant Eu* anomalies. Four of the samples are substantially depleted in LREE* relative to most of the Ski Hill Sequence, and have flat patterns, with TREE* lower than even those of the Intermediate Footwall samples. Although there may be two genetically different magma types represented in this assemblage, this is not indicated by any other trace elements, so an alteration control must be considered.

REE patterns for mafic to intermediate rocks from the mineralized Oriental Ore Horizon Sequence are shown in Figure 4d, and for dikes in Figure 4e. They are similar to those of the Ski Hill Sequence, having similar negative slopes and lack of Eu anomalies. One sample of mafic tuff, sample 2837-125, is strongly depleted in TREE*, and has a flat pattern like some of those in the Ski Hill Sequence or Intermediate Footwall. Mineralized sample 1872-649 shows no difference in REE pattern from those of any unmineralized samples.

Discussion

From the above observations, it must be said that, while there are suggestions of changes in REE distribution patterns accompanying mineralization which merit further detailed study, they are not consistent enough for routine application. The recognition of distinct differences in REE patterns between Archean mineralized and unmineralized felsic volcanics, and parallel differences for associated sills, raised two exciting possibilities, one for mineral exploration and the other for genetic understanding. The exploration implications are obvious from the possibility of clearly recognizing mineralized felsic volcanics by their flat REE patterns, a purely empirical tool which could be empirically tested.

Secondly, the similarity in REE patterns of mineralized volcanics and associated sills seems to imply a magmatic link with ore genesis. Thurston (1981) interpreted the flat REE patterns as reflecting the activity of mineralizing fluids, and subsequently (Thurston and Fryer, 1983) invoked petrogenetic processes reflecting contamination by older sialic crust and compositionally zoned magma chambers. Campbell et al. (1982) used the consistent presence of negative europium anomalies in their data to suggest that plagioclase fractionation was important to the mineralization process. Indeed, Campbell et al. (1981, page 45) had as an underlying theme to their interpretations that "we can be confident that [REE patterns] are governed by fundamental partial melting and fractionation processes", essentially those obeying the Rayleigh-type rules of crystal/liquid equilibria as outlined by Gast (1968) and Shaw (1970). However, there is abundant evidence of the profound effects of fluids at all stages, from magma crystallization to hydrothermal alteration (e.g. the review by Taylor and Fryer, 1983). Campbell et al. (1981) did not find any evidence of REE mobility in the pervasive low grade alteration envelopes surrounding the orebodies, but their later work (1983) has shown significant depletion of light and middle REE in the sub-ore alteration pipes. Nevertheless, Eu-depletion anomalies can be produced by feldspar-destructive alteration, even in low grade zones, and this may have caused the observed anomalies. Flat REE patterns have also been documented as alteration effects in a number of geological environments, and interpreted as resulting from LREE-leaching by chloride-bearing fluids, in line with the experimental results of Flynn and Burnham (1977). HREE enrichment can also be caused by the action of either F- or CO_2-bearing fluids (Taylor and Fryer, 1983). Thus, it cannot be assumed that either of the characteristics which Campbell et al. (1981) mention, *viz.* the flat patterns or Eu* anomalies, are primary features of the magmas or, similarly, that the mineralization had any primary magmatic cause.

Cu, Pb and Zn can be readily leached from footwall rocks. Indeed, such leaching is inherent to most genetic interpretations of volcanogenic massive sulfide deposits. Campbell et al. (1981, page 52) also suggested that Cu, Zn and Pb might behave as incompatible elements during silicate fractionation and concentrate in residual liquids, ultimately giving rise to ore deposits. If such processes resulted in the deposition of the large tonnages of these elements at Buchans, one might expect the effects on REEs and other trace elements to be equally large. Because such effects are absent from the Buchans volcanic and associated intrusive rocks, crystal fractionation could not have been an important factor in the formation of the Buchans orebodies. Therefore, the observed variations in REE patterns probably represent a range from the original igneous patterns to those modified as the result of leaching, transport and deposition by Cl-bearing aqueous fluids, according to earlier models suggested for such Kuroko-type deposits, e.g. by Sato (1971). The stable isotope data for S, O, and H suggest that such fluids were mainly seawater (Kowalik et al., 1981), although there may have been some magmatic input of ore metals (Sawkins and Kowalik, 1981).

While the distinctive REE patterns of Archean mineralized felsic volcanic rocks appear to be encouraging as an exploration tool, they do not appear to be universally applicable. This study strengthens the conclusion of Campbell et al. (1982) that "although all of the ore-bearing felsic volcanic rocks studied [by them] show the same distinctive flat REE pattern, it does not follow that all ore-bearing felsic volcanic rocks will have this type of REE geochemistry. Further testing is needed to clarify this point." It is probable that REE patterns of mineralized volcanic rocks will have to be explained in terms of multistage processes and controls, for example, differences in source regions, magmatic sources and processes, magmatic-hydrothermal processes and seawater convection. As with most other geochemical techniques, caution will be necessary in applying the results from one area to the rocks of another.

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GEOPHYSICAL MEASUREMENTS AT BUCHANS

by

P.G. Killeen[1], A.V. Dyck[1], C.J. Mwenifumbo[1] and A.K. Sinha[1]

A variety of surface and borehole geophysical measurements were carried out at Buchans, Newfoundland, during the period August 1982 to March 1983. These included: mise-a-la-masse, IP/resistivity, gamma-ray spectrometry, and Pulse EM techniques in boreholes and deep penetration EM techniques on the surface. These studies were conducted to evaluate the usefulness of the above techniques for outlining the mineralization and to evaluate their potential usefulness in the search for new ore in the Buchans area.

Drill hole mise-a-la-masse, IP/resistivity and natural gamma-ray spectrometry measurements were carried out over three prospects at Buchans. The mise-a-la-masse potential and IP measurements were conducted underground in the MacLean Extension orebody. Two drill holes at the Mudhole prospect and one at the Clementine prospect were logged with IP/resistivity and gamma-ray spectrometry.

The sulfide mineralization in the MacLean Extension, which has high conductivity relative to the host rock, was easily traced from hole to hole with the mise-a-la-masse technique. Drill hole resistivity logs from the Clementine prospect indicate that the conductivity contrast between the mineralization and the host rock is low, making this prospect a poor target for surface electrical and EM techniques. Examination of the raw gamma-ray spectral logs indicates that this may be a useful technique for characterizing the lithology in volcanic settings.

Deep electromagnetic surveys with Maxi-probe and Geonics EM-37 systems were carried out at two sites near Buchans, Newfoundland, during the summer of 1982. The first test site was over the Clementine prospect, which is an irregular sulfide body rich in sphalerite and barite at a depth of about 300 m from the surface. Because of the low conductivity of the orebody and great depth, the EM response on the ground was very weak. It is doubtful whether processing will improve the signal/noise ratio in data from this area.

The second test survey area was at Mary March, about 24 km from Buchans, where several shallow sulfide boulders have been found in the past. The EM survey located several weak conductors in the area, but it is not clear whether the weak response is due to the small size of the bodies or their poor electrical conductivity contrast with the country rock.

Experimental borehole pulse EM surveys were also carried out in selected locations to determine whether the technique could detect new orebodies in the Buchans geologic setting. Primarily due to the absence of suitable open boreholes for these tests, results are inconclusive. However, further analysis of these data is in progress to evaluate the significance of some low level anomalies recorded in the measurements.

Contribution to the Canada-Newfoundland co-operative minerals program 1982-84. Project funded by the Geological Survey of Canada.

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PRELIMINARY REPORT ON THE MINERALOGY OF THE TULKS MASSIVE SULFIDE DEPOSIT, BUCHANS AREA, NEWFOUNDLAND

by

J.L. Jambor[1]

The Tulks prospect, held jointly by Abitibi-Price and ASARCO, is a pyritite-type massive sulfide deposit in felsic metavolcanics about 40 km southwest of Buchans. Extensive diamond drilling begun in 1963 has delineated four massive sulfide lenses, designated T-1 to T-4, which total 700,000 to 800,000 tonnes grading about 5.6% Zn, 2.0% Pb, 1.3% Cu, 41 g/t Ag, and 0.4 g/t Au. The T-3 lens has been penetrated by underground workings, from which a bulk sample taken for milling tests gave unsatisfactory metal recoveries. Remnants of the feed for these milling tests and diamond-drill cores from the T-1, T-2 and T-3 lenses have been examined in polished sections to provide a reconnaissance evaluation of the Tulks mineralogy and its pertinence to the metallurgical problems.

Pyrite is the principal sulfide in all of the Tulks lenses, and sphalerite, galena and chalcopyrite account for all but trace amounts of the primary base metal values. Nearly all of the silver contents are attributable to argentian tetrahedrite, and electrum is sufficiently common to account for all of the gold values. Electron microprobe analyses of the sphalerite generally give iron contents of 2 to 3 wt.%, but values up to 8.6% Fe have been obtained for sphalerite in contact with pyrrhotite. Silver contents of tetrahedrite vary up to 10.3 wt.% Ag, and Sb-As values indicate that compositions extend from tetrahedrite to almost end-member tennantite. Analyses of two grains of electrum gave 67 and 69 wt.% Au.

In addition to the main sulfides, variable but generally small amounts of arsenopyrite, pyrrhotite, marcasite, magnetite, ilmenite and hematite are present in proportions that differ from lens to lens. The principal translucent minerals in the massive sulfide zones are quartz, muscovite (some grains containing percentage amounts of BaO), chlorite, barite, calcite, dolomite and celsian; others present in small amounts are rutile, sodic plagioclase, and unidentified barium silicates.

The textures and grain sizes of the sulfide minerals are suitable for ore-mineral liberation; most of the base metal sulfides are relatively coarse; finer fractions, even those in compact masses of pyrite, are predominantly interstitial to pyrite crystals or are along the grain boundaries of anhedral pyrite. Textures are generally simple and grain boundaries are smooth; complex sulfide intergrowths, although fairly commonly observed, are quantitatively rare. The principal negative factor for liberation is that some of the coarse grained pyrite contains small inclusions of galena, sphalerite and chalcopyrite which will not be separable.

Difficulties in processing the Tulks ore seem to be related mainly to supergene alteration and to oxidation of the sulfides, but at this stage of study the superior importance of one versus the other has not been established. Supergene alteration is evident from the presence of digenite, accompanied by minor covellite, which occurs in all lenses as thin rinds and hairline veinlets in chalcopyrite and sphalerite. Numerous microscopic masses of marcasite alteration are present in the T-1 and T-2 lenses, but have not yet been found in the incompletely studied T-3 lens. Oxidation of the sulfides is evident from goethite rims around voids, indistinct peripheral alteration of galena (to cerussite?), and in some cases the local presence of abundant anglesite. Supergene and oxidation effects are not continuous across the thickness of a lens, and more work is needed to establish the extent of these alterations and their quantitative importance.

Project funded by CANMET.

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GEOLOGY OF THE SKIDDER PROSPECT BUCHANS, NEWFOUNDLAND

Contract OSR83-00024

by

J. Wayne Pickett[1] and David M. Barbour[2]

Abstract

The Skidder prospect is a volcanogenic massive sulfide deposit hosted by Ordovician mafic volcanic rocks. Three types of sulfide-bearing zones occur in the deposit: (1) a quartz-pyrite stockwork(?) zone that contains very minor amounts of chalcopyrite and sphalerite, (2) a semimassive to massive, medium to coarse grained pyrite zone with minor chalcopyrite and sphalerite, and (3) a laminated massive sulfide zone consisting of fine to medium grained pyrite with lesser amounts (10 to 15%) of chalcopyrite and sphalerite. Brecciated, quartz-veined, massive and rarely bedded jasper is associated with the massive sulfide-bearing zones. Changes in secondary mineral assemblages outline distinct zones of alteration that are evident in cross-section up to 100 m above and below the deposit. These changes involve a disappearance of epidote and hematite, considerable reduction in carbonate and a large increase in chlorite and quartz contents near the sulfide-bearing zones. The Skidder prospect has more features in common with deposits in ophiolite sequences than with the polymetallic, Kuroko-type massive sulfide deposits typical of the Buchans area.

Introduction

The Skidder prospect, located 12 km south-southwest of the town of Buchans, central Newfoundland (NTS 12A/10) (Figure 1), is a volcanogenic massive sulfide deposit hosted within mafic volcanic rocks. The prospect was discovered in 1971 by ASARCO Inc.. Between 1971 and 1975, ASARCO Inc. (and during 1976 and 1977 in joint venture with Abititi-Price Mineral Resources) drilled 38 holes yielding a total of 7795 m core. The total probable and possible resources indicated by this drilling are approximately 900,000 tonnes, grading about 2% Cu, 2% Zn and containing minor amounts of Pb and Ag (D.M. Barbour, 1977, unpublished Abitibi-Price Mineral Resources report).

During the summer of 1983, the principal author completed detailed and some regional geological mapping in the vicinity of the deposit and relogged approximately 50 percent of the drill core as part of a geological and lithogeochemical study of the deposit. The study will form the basis of a Master of Science thesis to be completed by him at Memorial University of Newfoundland. This report concentrates on field aspects of the study, describing macroscopic features of (1) the regional rock types, (2) the host rocks to the deposit and (3) the alteration and ore types.

Regional Geology

The Skidder area is underlain by submarine mafic volcanic rocks. These rocks have previously been included in the Footwall Basalt unit of the Lower Buchans Subgroup, a calc-alkaline volcanic and volcaniclastic suite of rocks of island arc affinity (Thurlow and Swanson, 1981). The Footwall Basalt unit was described by these authors as "the lowermost unit of the Buchans Group..." consisting of a "thick (approximately 3800 m), laterally continuous sequence composed mainly of basaltic pillow lava and pillow breccia interbedded with lesser pyroclastics and discontinuous lenses of multicolored, bedded chert."

Field examinations carried out during this study indicate differences between 'typical' rocks of the Footwall Basalt unit and the rocks that outcrop in the southern two-thirds of the area shown in Figure 1, including the host rocks of the prospect. Rocks in the vicinity of the prospect and in the previously mentioned area are

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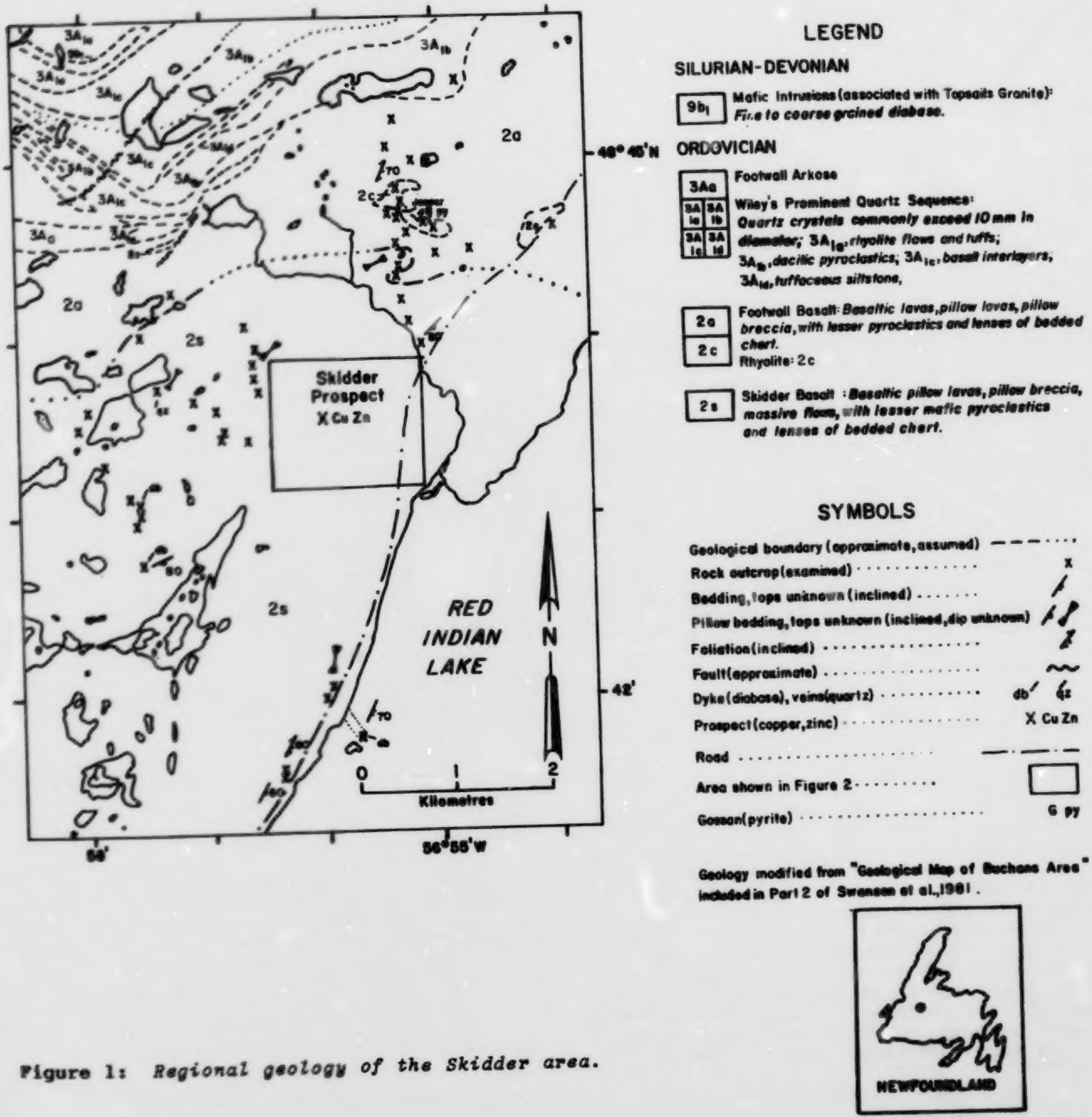
generally greener in color and presumably more chloritic than the less altered dark green-black rocks typical of the Footwall Basalt unit. The flows contain fewer amygdules and the amygdules, where present, are smaller in size than those that occur within mafic flows exposed in other sections of the Footwall Basalt unit. This may indicate that these flows were deposited in a deeper water environment than those the flows typical of the Footwall Basalt unit (Jones, 1969). Pillows with variolitic rims are common in areas near the prospect but not in other areas of Footwall Basalt. Also, the rocks near the flows and lesser mafic pyroclastics. The rocks are generally medium green to medium gray and are fine to medium grained.

Pillows in the Skidder Basalt are dominantly small (15 to 30 cm in diameter) but in certain areas are up to 1 m in diameter and are rounded but irregular in cross-section. Interpillow material is generally more chloritic than that making up the pillows themselves, and in some areas small irregular jasper bodies fill pillow interstices. Some pillows have


3A1a
3A1b
3A1c
3A1d
3Aa
2a
2c
2s
48°45'N
42'
58'
56°56'W
Skidder Prospect
X Cu Zn
RED INDIAN LAKE
N
0
1
2
Kilometres
LEGEND
SILURIAN-DEVONIAN
9b1 Mafic Intrusions (associated with Topsails Granite): Fine to coarse grained diabase.
ORDOVICIAN
3Aa Footwall Arkose
3A1a 3A1b 3A1c 3A1d Wiley's Prominent Quartz Sequence: Quartz crystals commonly exceed 10 mm in diameter; 3A1a, rhyolite flows and tuffs; 3A1b, dacitic pyroclastics; 3A1c, basalt interlayers; 3A1d, tuffaceous siltstone,
2a 2c Footwall Basalt: Basaltic lavas, pillow lavas, pillow breccia, with lesser pyroclastics and lenses of bedded chert. Rhyolite: 2c
2s Skidder Basalt: Basaltic pillow lavas, pillow breccia, massive flows, with lesser mafic pyroclastics and lenses of bedded chert.
SYMBOLS
Geological boundary (approximate, assumed)
Rock outcrop (examined)
Bedding, tops unknown (inclined)
Pillow bedding, tops unknown (inclined, dip unknown)
Foliation (inclined)
Fault (approximate)
Dyke (diabase), veins (quartz) db qz
Prospect (copper, zinc) X Cu Zn
Road
Area shown in Figure 2
Gossan (pyrite) G py
NEWFOUNDLAND
Index Map

Geology modified from "Geological Map of Buchans Area" included in Part 2 of Swanson et al., 1981.

Figure 1: *Regional geology of the Skidder area.*

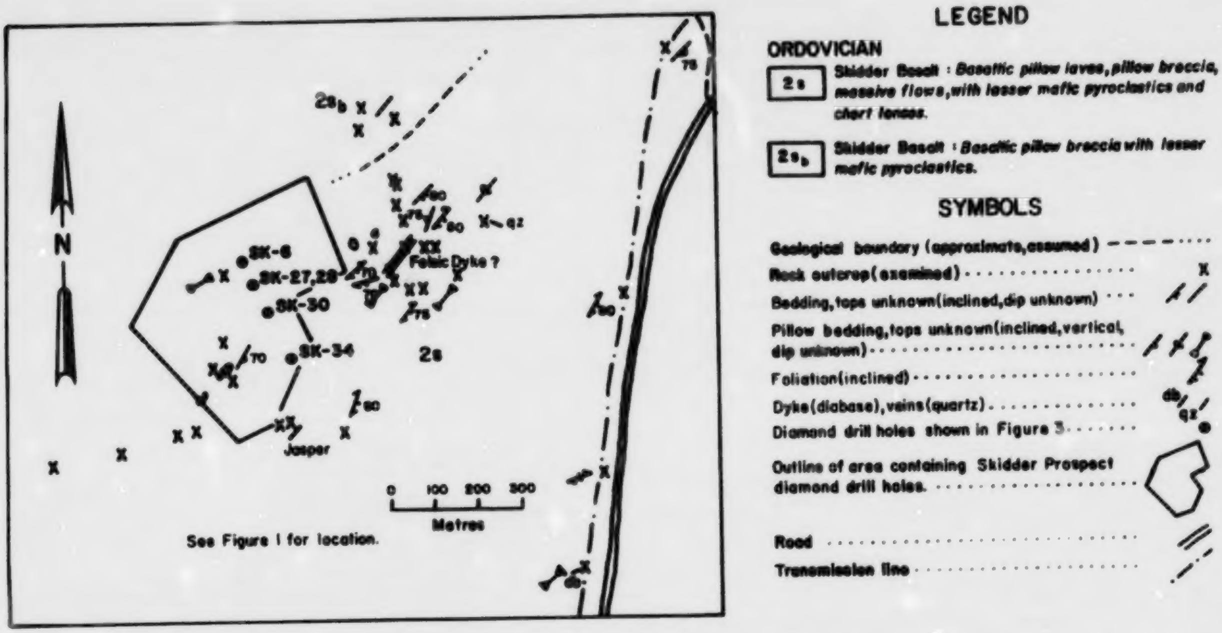

2sb
2s
N
SK-6
SK-27,28
SK-30
SK-34
Felsic Dyke ?
Jasper
qz
0 100 200 300
Metres
See Figure 1 for location.
LEGEND
ORDOVICIAN
2s Skidder Basalt : Basaltic pillow lavas, pillow breccia, massive flows, with lesser mafic pyroclastics and chert lenses.
2sb Skidder Basalt : Basaltic pillow breccia with lesser mafic pyroclastics.
SYMBOLS
Geological boundary (approximate, assumed)
Rock outcrop (examined)
Bedding, tops unknown (inclined, dip unknown)
Pillow bedding, tops unknown (inclined, vertical, dip unknown)
Foliation (inclined)
Dyke (diabase), veins (quartz)
db
qz
Diamond drill holes shown in Figure 3
Outline of area containing Skidder Prospect diamond drill holes.
Road
Transmission line

Figure 2: *Local geology of the Skidder prospect.*

variolitic rims characterized by light gray variolites, 3 to 6 mm in diameter, within a of the Skidder basalts and those of the Footwall Basalt unit will be undertaken later in this study.

Individual flow units plus pyroclastic and sedimentary beds examined within both the Skidder Basalt and Footwall Basalt units generally strike northeasterly and dip steeply to the southeast (Figure 1). Pillows predominantly indicate a northwest facing, but most pillows are not suitable for determining stratigraphic tops.

Dean (1977) suggested a Late Ordovician to Middle Silurian age for the Buchans Group based on general stratigraphic relationships. Subsequently, Bell and Blenkinsop (1981) reported a 447 ± 18 Ma whole rock Rb/Sr date for the Buchans Group, which supports a Middle Ordovician to Early Silurian age. However, conodonts recovered from carbonate clasts within Buchans Group breccia units suggest a slightly older, early Middle Ordovician Llanvirnian age for the carbonate clasts (Nowlan and Thurlow, *in preparation*). The clasts are considered by these authors to be of local origin and, thus, their age to be representative of the age of the Buchans Group. The Skidder Basalt appears to be conformably overlain by the Footwall Basalt unit of the Buchans Group; both are presumed to be of similar age.

Local Geology

Skidder Basalt

The Skidder Basalt (unit 2s, Figures 1 and 2) comprises a sequence of basaltic pillow lavas, pillow breccias, massive green chloritic matrix. These variolite-rimmed pillows have been noted in drill core structurally beneath the massive sulfide deposit, as well as in outcrop to the south of and presumably stratigraphically below the deposit.

Pillow breccias in the area include angular basaltic fragments within a chloritic and, in many instances, epidote-rich matrix. Other pillow breccias, particularly those noted in drill core, are more characteristic of isolated pillow breccia (Carlisle, 1963). These breccias consist of rounded 'mini-pillows' that are 5 to 20 cm in diameter and are located, in most places, within a greener presumably more chloritic matrix. The chloritic matrix generally makes up 30 to 60 per cent of the rock. In many cases, these 'mini-pillows' have variolitic rims similar to the variolitic pillow rims described previously.

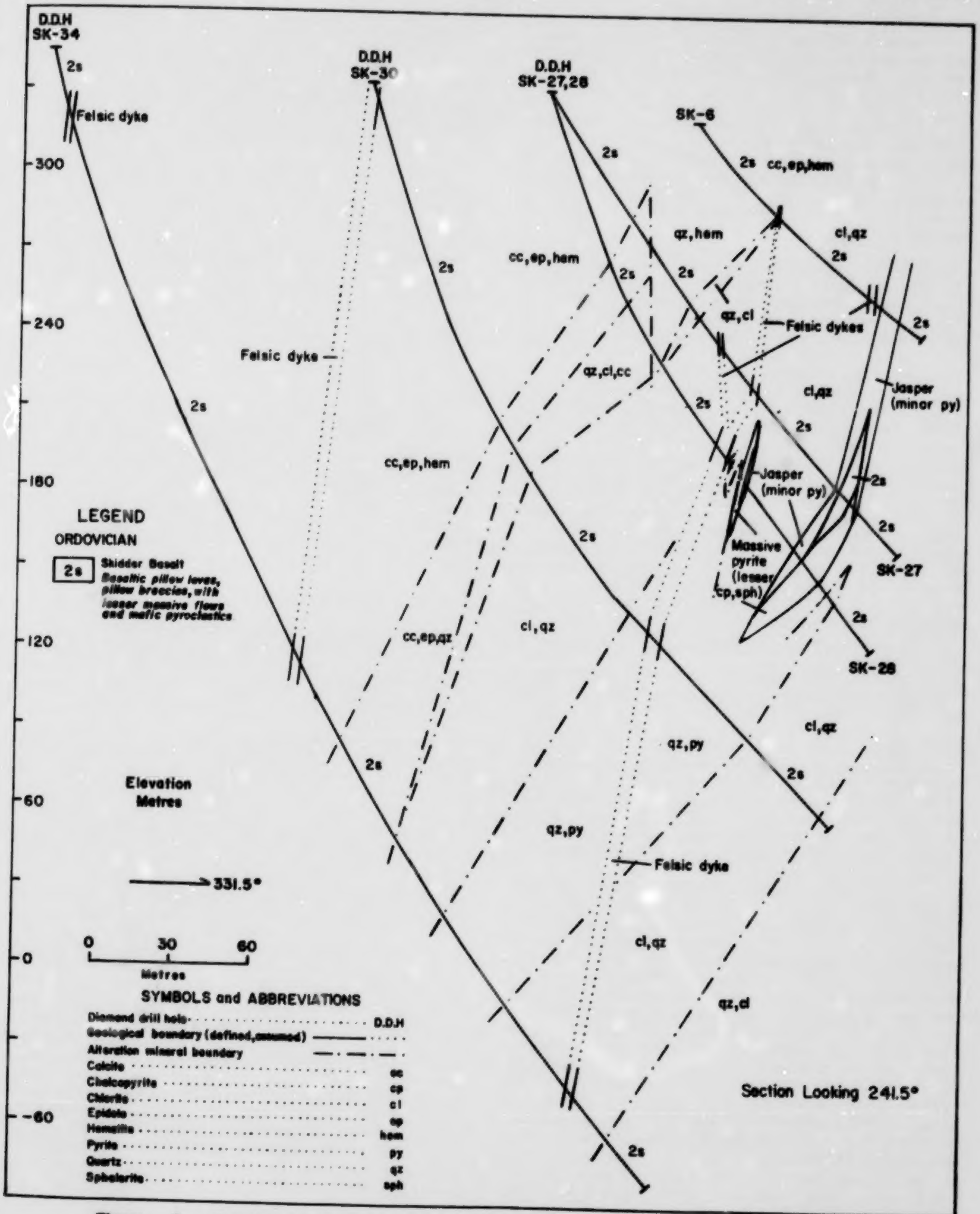

D.D.H
SK-34
D.D.H
SK-30
D.D.H
SK-27,28
SK-6
2s
Felsic dyke
cc,ep,hem
qz,hem
cl,qz
qz,cl
Felsic dykes
qz,cl,cc
Felsic dyke
Jasper
(minor py)
Jasper
(minor py)
Massive
pyrite
(lesser
cp,sph)
SK-27
SK-28
cc,ep,qz
cl,qz
qz,py
qz,py
Felsic dyke
cl,qz
qz,cl
Section Looking 241.5°
300
240
180
120
60
0
-60
LEGEND
ORDOVICIAN
2s Skidder Basalt
Basaltic pillow lavas, pillow breccias, with lesser massive flows and mafic pyroclastics
Elevation
Metres
331.5°
0 30 60
Metres
SYMBOLS and ABBREVIATIONS
Diamond drill hole D.D.H
Geological boundary (defined, assumed)
Alteration mineral boundary
Calcite cc
Chalcopyrite cp
Chlorite cl
Epidote ep
Hematite hem
Pyrite py
Quartz qz
Sphalerite sph

Figure 3. Cross-section through the Skidder prospect showing the alteration zones that flank the sulphide-bearing units. See Figure 77.2 for location of diamond drillholes.

Massive flows are also medium gray to medium green and fine to medium grained. Locally, the flows have been autoclastically brecciated.

An estimated 30 per cent of the massive and pillowed flows are amygdaloidal. These amygdules, dominantly calcite and to a lesser extent epidote and chlorite, are generally 2 to 4 mm in diameter and, where present, make up less than 10 per cent of the rock.

Mafic pyroclastics consist dominantly of medium green-gray ash-crystal tuffs. These tuffs have an overall massive appearance and are poorly bedded. Bedding planes are visible only on the weathered surface thus making them difficult to distinguish from massive flows in drill core. Other mafic pyroclastics include aquagene tuffs (?) that were noted only in core, generally close to the massive sulfide zone. The tuffs consist of olive green, very fine grained, discontinuous, anastomosing layers (locally 1 to 5 cm in maximum dimension) that occur within a very dark green, fine grained, highly chloritic matrix. One outcrop of matrix-supported lapilli tuff is exposed 400 m northeast of the prospect. The lapilli are angular, 2 to 8 cm in length and make up approximately 10 per cent of the unit. The matrix to the lapilli is chloritic to cherty.

Jasper and red cherty siltstone occur as interpillow material and as discontinuous massive, in rare instances, bedded units (Figures 1, 2 and 3).

Mafic intrusive rocks exposed in the area include fine to medium grained diabase dikes and coarser grained gabbroic bodies (dikes?). The latter occur in two outcrops west of the Skidder prospect. In hand specimen, these rocks contain visible ophitic intergrowths of plagioclase and pyroxene.

Light gray-green, fine grained felsic dikes were noted in core (Figure 3) and also in two outcrops east of the prospect (Figure 2). The dikes strike approximately parallel to the local stratigraphy and dip steeply to the southeast (Figure 3). In some sections, they contain approximately 5 percent quartz and feldspar phenocrysts, 1 to 3 mm in diameter, that occur in very fine grained matrix. In many instances, layering is present in these dikes within 30 cm of their contact with adjacent mafic units. This layering is defined by alternating light and dark gray-green to buff colored 0.5 to 1 cm wide zones that parallel the dike contact.

Footwall Basalt

Rocks of the Footwall Basalt unit (unit 2a, Figure 1) examined in the study area are generally basaltic pillow lavas and flow breccias. These rocks are green-black, fine grained, and generally amygdaloidal: the amygdules are usually slightly flattened, 0.5 to 1.5 cm in diameter and calcite-filled, and comprise up to 20 per cent of the rock. Pillows are slightly flattened, 0.5 to 1 m in diameter, and in some areas contain amygdules arranged in a roughly concentric pattern. The breccia units consist of angular gray-black basalt fragments from 0.5 to several centimetres across that occur within a fine grained, green-black, presumably more chloritic matrix.

Rhyolite(?)

A small body of rhyolite(?) (possibly silicified mafic volcanic rock(?)) outcrops approximately 2 km northeast of the Skidder prospect (unit 2c, Figure 1). The rhyolite(?) is gray, fine grained and massive. A one metre thick unit of jasper separates the gray rhyolite(?) from the Footwall Basalt in an exposed contact of these units (Figure 1).

Sulfide-bearing Zones

The massive and disseminated sulfides are hosted within basaltic pillow lavas, pillow breccias and aquagene tuffs of the Skidder Basalt unit. The sulfide-bearing units are of three types:

(1) The first consists of essentially massive silicified volcanics with quartz veins that contain 30 to 70 percent pyrite plus rare chalcopyrite and sphalerite (see qz, py zone, Figure 3). Quartz and pyrite make up approximately 80 percent of this unit with the remaining 20 percent consisting of scattered, discontinuous chlorite-rich masses, some of which contain variolites. These masses are presumably altered remnants of the original rock unit. The pyrite is generally medium to coarse grained and occurs as veins, massive bodies and disseminated cubes within the quartz. The chalcopyrite and sphalerite occur typically along the margins of quartz veins.

(2) The second type consists of semimassive to massive, nonbedded, medium to coarse grained pyrite with 5 to 15 percent quartz and lesser calcite

gangue. Rare fine grained chalcopyrite- and sphalerite-rich zones occur within the massive pyrite.

(3) Laminated, fine to medium grained pyrite with 10 to 15 percent interlaminated chalcopyrite and sphalerite constitute the third type.

The massive sulfides (types 2 and 3) occur as two main lens-shaped bodies. The first plunges 37° westward with a known length of 380 m along the plunge and has a maximum width of 90 m, a maximum known thickness of 11 m and an average thickness of 4.1 m. The second lens plunges 57° westward with a defined length of 243 m, has a maximum width of 68 m, a maximum known thickness of 6.7 m and an average thickness of 3.4 m (D.M. Barbour, 1977, unpublished Abitibi-Price Mineral Resources report).

In some sections, jasper occurs at the contact of the massive sulfide lenses with adjacent units (Figure 3). It occurs generally as massive units that are in many areas brecciated and veined by quartz. The jasper units, which in very rare instances show bedding, range from 0.3 to 8 m in thickness.

Regional Alteration

Rocks of the Skidder Basalt examined in outcrop generally contain epidote, calcite and, in places, chlorite as veins and amygdule fillings. In addition, alteration of mafic minerals to chlorite is ubiquitous. Alteration to epidote, particularly in the matrix to pillow breccia fragments, is also pervasive in some areas. Quartz veins are limited in extent and, where observed in outcrops away from the massive-sulfide-bearing zones, are present as 1 to 3 cm wide, subparallel veins that are probably related to mobilization of silica during regional metamorphism. Basalts exposed in the Halfway Mountain area, approximately 2 km southwest of the prospect, contain fibrous actinolite rossettes as vein fillings in addition to lesser amounts of epidote and carbonate.

Local Alteration

A zoned sequence of alteration minerals is present for approximately 100 m structurally above and below the sulfide-bearing zones. Calcite, epidote and lesser amounts of hematite make up the first alteration assemblage, furthest from the sulfide-bearing zones (Figure 3). The calcite and epidote occur as veinlets and amygdule fillings. 'Blotches' of epidote, generally 5 to 15 cm in diameter, are also widely distributed in some areas. Hematite is less abundant than epidote and calcite, and is more prevalent in pillow breccia zones. Hematite occurs as veins, and in some areas is disseminated throughout the unit. The remainder of the assemblages are arranged below in order of increasing proximity to the sulfide-bearing zones.

The absence of hematite and the occurrence of quartz along or with calcite as veinlets and amygdule fillings define the second alteration assemblage (Figure 3).

An increase in the amount of chlorite, the lack of epidote and the presence of fine grained, gray siliceous areas mark the third alteration assemblage (Figure 3). The siliceous sections characteristically have quartz veinlets throughout and range from 5 to 20 cm in length in drill core.

The fourth alteration assemblage is characterized by a marked increase in chlorite and a decrease in calcite relative to the first two zones (Figure 3). In some areas, chlorite makes up an estimated 50 to 60 percent of the rock. Pervasively silicified areas and quartz veinlets are present, similar to those in the previous zone.

The fifth assemblage, the quartz-pyrite zone (qz, py zone, Figure 3), is the most extensively altered of the zones, with an estimated 80 percent of the rock replaced by quartz and pyrite.

Discussion of Alteration Assemblages

Mottl (1983) summarized results of experimental studies of basalt-seawater interaction and the relationship of these results to the alteration minerals in metabasalts and metadiabase dredged from the Mid-Atlantic Ridge. In this summary, Mottl suggested the following sequences of mineral assemblages to be characteristic of increasing seawater/rock ratios within the temperature range 250°C to 450°C: (1) chlorite(chl)-albite(ab)-epidote(ep)-actinolite(act), (2) chl-ab-ep-act-quartz (qtz), (3) chl-ab-qtz, and (4) chl-qtz. The secondary mineral assemblages that define the alteration zone structurally above and below the sulfide units of the Skidder prospect match reasonably well the assemblages described by Mottl (1983), and possibly indicate that more hydrothermal fluid passed through the rocks closer to the sulfide-bearing unit.

General Discussion

The Skidder prospect has more similarities to massive sulfide deposits in ophiolite sequences (Franklin et al., 1981; Constantinou and Govett, 1973; Constantinou, 1980) than have other deposits in the Buchans area, which are considered similar to the Kuroko ore deposits of Japan (Thurlow, 1973, 1981; Thurlow et al., 1975). The similarity to ophiolite-associated massive sulfide deposits is indicated by the following: (1) the sulfides are hosted by mafic pillow lavas and related pillow breccias; (2) pyrite, chalcopyrite and sphalerite are the dominant sulfides with only very minor galena; (3) in some areas, jasper occurs at contacts of the massive sulfide zones with adjacent units; and (4) felsic rocks and high barite content characteristic of other Buchans sulfide deposits are lacking.

Summary

The Skidder prospect is a massive sulfide deposit that occurs in pillowed basalts, associated pillow breccias and lesser mafic pyroclastics. The deposit consists of three types of sulfide-bearing units, (1) a quartz-pyrite stockwork(?) zone that contains rare chalcopyrite and sphalerite, (2) a semimassive to massive nonbedded pyrite zone with minor chalcopyrite and sphalerite, and (3) a laminated massive sulfide zone consisting of fine to medium grained pyrite with lesser amounts of chalcopyrite and sphalerite. Brecciated, quartz-veined, massive and rarely bedded jasper is associated with the massive sulfides. Distinct alteration zones characterized by secondary mineral assemblages occur within 100 m of the sulfide-bearing unit.

The mafic rocks surrounding the Skidder prospect, including those that host it, are different from "typical" rocks of the Buchans Footwall Basalt unit. On the basis of these differences, the rocks surrounding and including the Skidder prospect have been assigned to a new unit called the Skidder Basalt.

Acknowledgements

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GEOLOGY OF THE WEST HALF OF THE DOLLAND BROOK MAP AREA (11P/15), SOUTHERN NEWFOUNDLAND

by

R. Frank Blackwood

Abstract

The Ordovician Bay du Nord Group forms a central wedge of metasedimentary and metavolcanic rocks in the Dolland Brook (11P/15) map area. It is interpreted to represent a turbidite sequence containing distal submarine felsic volcanic rocks. The group underwent D_1 *recumbent isoclinal folding and subsequent* D_2 *upright folding. Metamorphism in the group increased during* D_1 *toward synkinematic granites and migmatites which occur in the southern part of the map area. The granites were also intruded during the development of* D_1 *shear zones, now represented by narrow mylonite zones. A post-*D_1 *- syn-*D_2 *granite intruded the northern part of the area, resulting in a thermal aureole in the adjacent part of the Bay du Nord Group. Sulfide and scheelite mineralization is associated mostly with the felsic volcanic rocks and the late granite.*

Introduction

The Dolland Brook (11P/15) map area is located north of Francois on Newfoundland's south coast. The Grey River flows along its western boundary. The area is accessible by helicopter and fixed wing aircraft; the southern part may be reached by small boat from the coastal community of Grey River. The communities of Grey River and Francois on the coast south of the map area are regular stops on CN Marine's south coast ferry run.

Mapping of the west half of the Dolland Brook area on a 1:50,000 scale was completed during the 1983 field season; the east half was completed by Dickson and Delaney *(this volume)*. Exposure is poor in the northern part of the map area, fair in the central portion, and excellent in the south.

The Dolland Brook area was mapped on a 1:63,360 scale for Buchans Mining Company Limited (Scott and Conn, 1950). This work was updated by the American Smelting and Refining Company in 1968. It was also mapped on a 1:250,000 scale by the Geological Survey of Canada (Williams, 1971) as part of the larger Burgeo map area. A compilation map of Dolland Brook (Smyth, 1979) was based on previous work and some reconnaissance investigations.

General Geology

The Dolland Brook map area (Figure 1) is sited in the eastern part of the Hermitage Flexure (Williams et al., 1970), a generally west trending, sinuous configuration of rock units that occurs in southern Newfoundland. Structural and lithostratigraphic elements have a west or northwest trend in the map area. The metasedimentary and metavolcanic rocks are included in, and continuous with, the Ordovician Bay du Nord Group to the west (Cooper, 1954; Chorlton, 1980a,b; O'Brien, 1983; O'Brien and Tomlin, *this volume)*. They are also the probable equivalent of the Ordovician Baie d'Espoir Group (Jewell, 1939; Colman-Sadd, 1974, 1976) to the east.

Rock units in the west half of the Dolland Brook area may be grouped into three broad subdivisions:

(1) a central wedge of metasedimentary and metavolcanic rocks of the Bay du Nord Group;

(2) a southern terrain of migmatite and foliated granitoids; and

(3) a northern terrain of little deformed biotite and two-mica granite (the North Bay Granite).

Bay du Nord Group (Units 1-5)

The Bay du Nord Group consists of four lithostratigraphic units (Units 1, 3-5) with an outcrop pattern mostly controlled by a west trending, moderately plunging F_2 syncline. The definition and distribution of an additional unit (Unit 2) iscontrolled by the degree of metamorphism and remobilization associated with granite intrusion.

Unit 1 is a belt of metasedimentary rocks that occurs between the narrow band of felsic volcanics (Unit 3) on the northern limb of the F_2 syncline, and the

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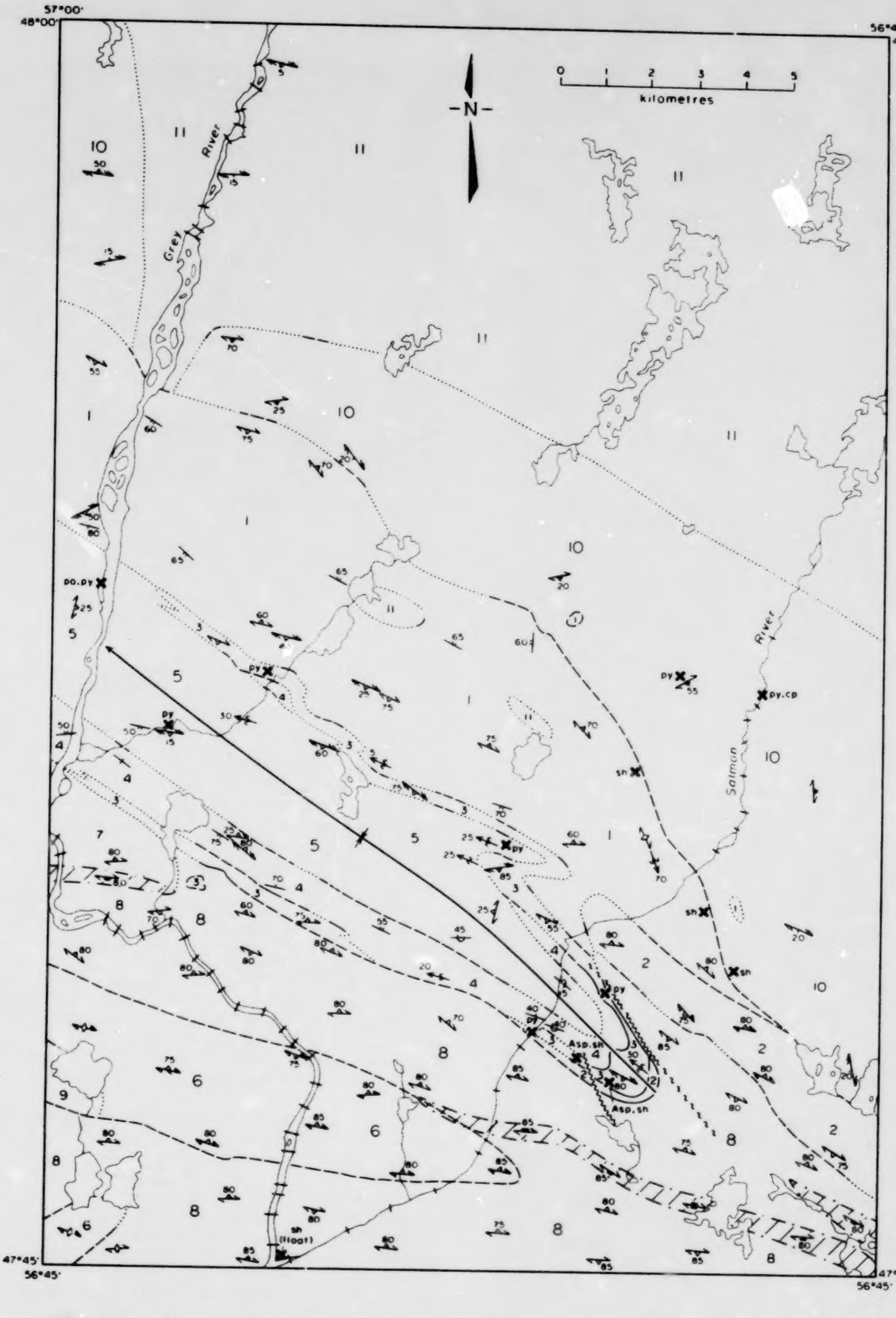
Contribution to the Canada-Newfoundland co-operative minerals program 1982-84. Project funded by the Newfoundland Department of Mines and Energy.


57°00'
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kilometres
N
Grey River
Salmon River
po.py
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sn (float)
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56°45'
47°45'
56°45'

Figure 1: *Geological map of the west half of the Dolland Brook (11P/15) map area, southwestern Newfoundland.*

LEGEND

DEVONIAN AND EARLIER

North Bay Granite (Units 10 and 11)

11 Medium to coarse grained, equigranular to coarsely porphyritic biotite-muscovite granite; includes minor biotite granite.

10 Medium to coarse grained, equigranular to coarsely porphyritic biotite granite; includes minor two-mica granite.

9 Fine grained, equigranular, minor biotite - rare muscovite granite.

8 Medium to coarse grained, equigranular to finely porphyritic biotite granite.

7 Coarse grained, coarsely porphyritic biotite - minor hornblende granite.

ORDOVICIAN(?)

6 Crudely banded granitoid and migmatite with minor pelite and amphibolite inclusions.

Bay Du Nord Group (Units 1-5)

5 Gray to black slate/phyllite; locally contains thin siltstone and fine grained sandstone beds.

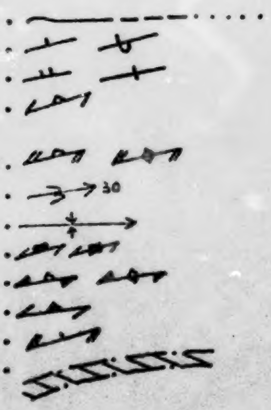
4 Sandstone, siltstone and slate locally containing pebble to cobble conglomerate, including quartz-pebble conglomerate.

3 Fine grained felsic tuff, minor quartz-feldspar lapilli tuff and minor volcanic breccia; locally contains interbedded graphitic pelite.

2 Pelitic and semipelitic schist and migmatite with concordant leucogranite veins.

1 Psammite, semipelite and pelite with minor sandstone, conglomerate, graphitic pelite, and amphibolite.

SYMBOLS



Geological contact (defined, approximate, assumed).........
Bedding, tops known (inclined, overturned)...................
Bedding, tops unknown (inclined, vertical)...................
Regional cleavage, schistosity, S_1 (inclined)...............
Crenulation or strain-slip cleavage, S_2 (inclined, vertical)..
Minor F_2 fold axes..
Large scale F_2 fold (syncline)..............................
Mylonitic foliation (inclined, vertical)......................
Migmatitic banding (inclined, vertical).......................
Weak to moderate biotite alignment (inclined)..............
Fracture cleavage (inclined)...................................
Mylonite zone...

southern boundary of the North Bay Granite. Consequently, it is dominated by the recrystallization and porphyroblast development that occurs within the granite's thermal aureole. Garnetiferous leucogranite veins are also common. The unit consists predominantly of laminated pelite, semipelite and psammite. Thin (0.5 to 1.0 mm) pelitic laminations in the gray psammites are accentuated by porphyroblastic biotite growth. Where interbedded, psammite beds are 2 to 6 cm thick and the pelite/semipelite beds are 0.5 to 2 cm thick. Minor graphitic pelite and amphibolite occur in some exposures; an approximately 1 m thick band of quartz-pebble conglomerate was found in one outcrop. Locally a clastic texture is discernible in the more siliceous psammite and in minor thin beds of quartzite. Graded sandstone and interbedded siltstone beds, 1 to 10 cm thick, form the southernmost outcrop of Unit 1 on Grey River; they are the likely protoliths for the more metamorphosed rocks elsewhere in the unit.

Fine to medium grained biotite and muscovite occur on the foliation planes of the pelite and semipelite which range from phyllite to schist depending upon proximity to the North Bay Granite. The quartzofeldspathic rocks commonly exhibit a granoblastic texture. Locally, along the granite contact, quartz segregations and granite veining give a migmatitic aspect to the schists. Biotite, muscovite, garnet, andalusite and hornblende commonly occur as porphyroblasts throughout Unit 1. These overprint a fine, penetrative foliation that is generally coplanar to bedding and axial planar to small scale F_1 folds. A second strain-slip cleavage variably transposes S_1 and is axial planar to small-scale F_2 folds which locally produce Type 3 interference patterns (Ramsay, 1967) (Plate 1).

Unit 2 is interpreted as the higher grade metamorphic version of Unit 1. It occurs as a narrow band between two granitoids (Units 8 and 10) east of Salmon River and as a narrower band around the hinge of the F_2 fold. The unit consists mostly of semipelitic schists that are intruded by a profusion of concordant leucogranite veins and foliated, equigranular biotite granite. Biotite, muscovite and garnet porphyroblasts are common throughout. A significant portion of the larger band may best be described as migmatite; wispy, partially assimilated pelitic inclusions occur as schlieren in a crudely banded granitoid host. Locally large rafts of graphitic pelite and semipelite with quartz and granitoid sweats occur within the migmatite zone. The regional S_1 foliation is axial planar to small scale isoclinal F_1 folds which are commonly defined by garnetiferous leucogranite veins. In the large scale F_2 fold hinge, both limbs of F_1 isoclines are overprinted by the second crenulation or strain-slip cleavage.

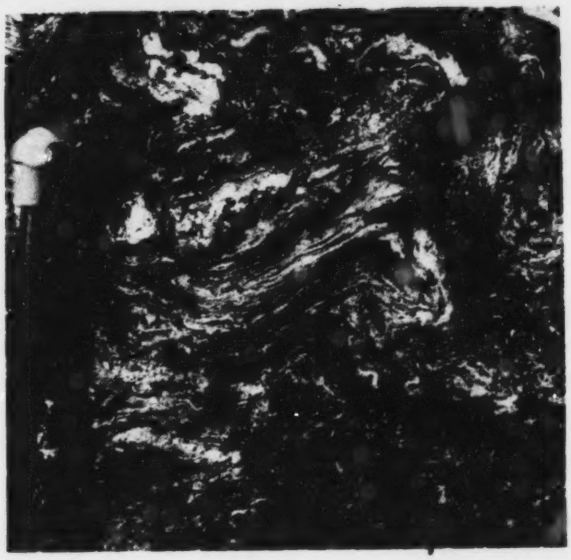


Plate 1: *F_2 refolding of isoclinal F_1 folds producing Type 3 interference patterns in quartz-injected pelite (unit 1). Note axial planar S_2 crenulation cleavage.*

Unit 3 is an approximately 200 to 300 m wide band of pinkish to grayish white weathering, very fine grained, generally siliceous felsic tuff that provides a useful marker in delineating the F_2 syncline in the map area. Although zones of lapilli tuff rich in quartz and feldspar crystals occur, most of the tuffs are either free of macroscopic crystals or contain just a few 'eyes' of quartz and feldspar 1 to 4 mm across. Laminations and discontinuous color and/or compositional variations, 1 to 2 mm thick, are interpreted as primary structures (Plate 2). Minor light gray chert and massive rhyolite occur locally. In the hinge zone of the F_2 fold, volcanic breccia is well developed and consists of elongate 1 to 15 cm long clasts of light gray felsic tuff in a very fine grained darker gray felsic matrix. Some of the clasts have primary banding. Black graphitic pelite locally occurs interbedded with the felsic volcanics. A conformable contact between the tuffs and the overlying sedimentary rocks is indicated by the gradational change in color and composition of the tuffs such that they become less siliceous and of a darker gray color near the contact with the gray sandstone, slate and pelite. Quartz veining, mostly concordant with the primary laminations, is common throughout Unit 3. Locally, rusty zones occur in the tuffs.

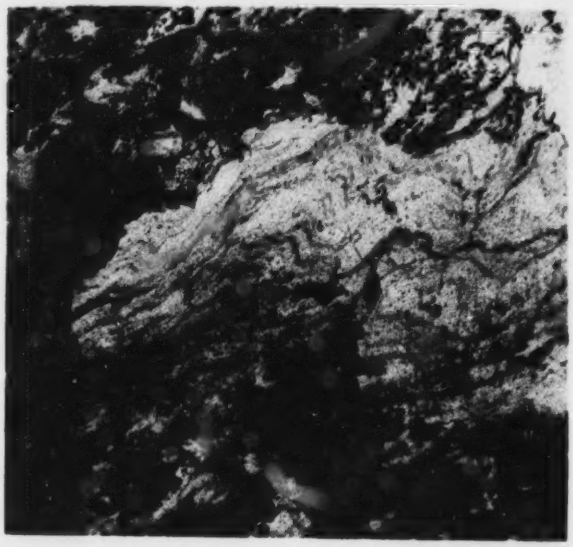


Plate 2: *Laminated felsic tuff showing F_2 folds (unit 3).*

A penetrative fabric is developed parallel to the laminations and is axial planar to isoclinal F_1 folds of the laminations and concordant quartz veins. Biotite streaks and minor muscovite occur on the S_1 fabric planes. A fracture cleavage is axial planar to small scale F_2 folds which typically produce Type III interference patterns (Ramsay, 1967). The moderate westward plunge of the large scale F_2 structure produces the widest areal extent of Unit 3 volcanics in the hinge zone of the fold.

Unit 4 is a laterally discontinuous clastic sequence that structurally and stratigraphically overlies the felsic volcanics of Unit 3. It consists mostly of fine to coarse grained, 4 to 30 cm thick, gray sandstone beds with interbedded siltstone and gray slate. Interpreted as turbidites, these rocks include sandstone beds which, on Salmon River, have sharp bases and grade over several centimetres into laminated siltstone with shale caps (Plate 3), interpreted as partial Bouma sequences (Bouma, 1962). Quartz and white feldspar comprise the sandstone which, west of Salmon River, is massive and contains interbeds of conspicuous white quartz-pebble conglomerate and pebbly sandstone. Minor felsite clasts and shale intraclasts also occur in the pebble conglomerate which varies from clast- to matrix-supported. Pebble and cobble conglomerate, mostly matrix-supported, occurs in the turbidites on Salmon River (Plate 4). Clasts are mainly felsic volcanics but also include quartz, fine to medium grained plagiogranite, sandstone, siltstone, shale and quartz-feldspar porphyry. Locally, isolated cobbles 'float' in interbedded, coarse grained sandstone. Some of the felsic volcanics show pre-inclusion quartz veins, a possible source for the quartz pebble horizons. Associated granule conglomerate forms channel scours in underlying laminated sandstone and siltstone.

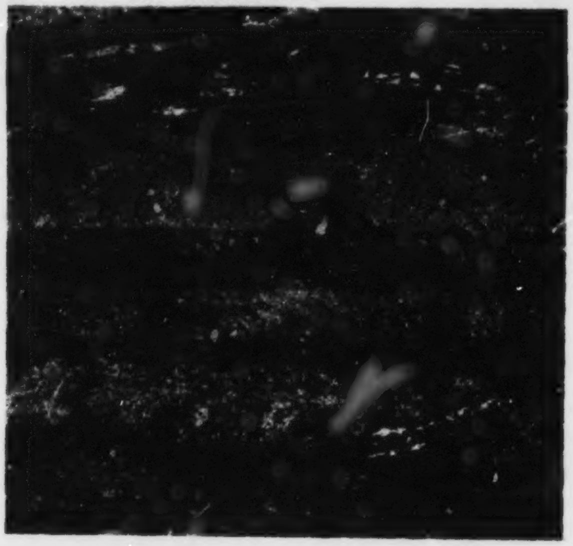


Plate 3: *Sandstone beds grade into laminated siltstone and shale (unit 4).*

Plate 4: *Partially clast-supported polymictic conglomerate (unit 4). Note pre-inclusion quartz veining in felsic volcanic clast.*

Large, rounded to angular fragments of felsic volcanics, up to 2 m long, occur as isolated clasts in laminated sandstone and siltstone along the contact between Units 3 and 4 (Plate 5). Graded sandstone beds also appear to be right way up close to the felsic volcanics. These observations suggest that Unit 4 clastics stratigraphically overlie Unit 3 volcanics and that the large scale F_2 fold is in fact a syncline as well as a synform. Overturned isoclinal F_1 folds in Unit 4 along Salmon River locally produce overturned beds but these are small scale, second order structures (wavelength of 10 m or less) and do not appear to have affected the overall stratigraphy. A penetrative S_1 foliation is coplanar with bedding and axial planar to the F_1 folds. The S_2 strain-slip cleavage is locally developed. The metamorphic grade increases within Unit 4 towards the felsic volcanics of Unit 3 along both limbs of the F_2 fold as these areas are influenced by intrusive granitic rocks. Porphyroblastic muscovite commonly occurs in the southern parts of Unit 4.

Plate 5: ***Felsic volcanic clasts in sandstone at base of unit 4.***

Unit 5 is disposed in the core of the F_2 syncline and consists mostly of gray or black slate and phyllite. Along the contact with Unit 4, fine grained sandstone and siltstone are interbedded. Elsewhere, thin sandstone beds occur (Plate 6), and range from 0.5 to 3 cm in thickness with an average of 1 cm; these are commonly reddish brown.The slate is characterized by a pronounced slaty cleavage (S_1) which is variably dipping due to F_2 folding. This main fabric becomes phyllitic in areas of slightly higher metamorphic grade; small corderite and/or andalusite porphyroblasts are locally developed in the phyllite. The second fabric is a locally developed strain-slip or crenulation cleavage with variable dip and strike.

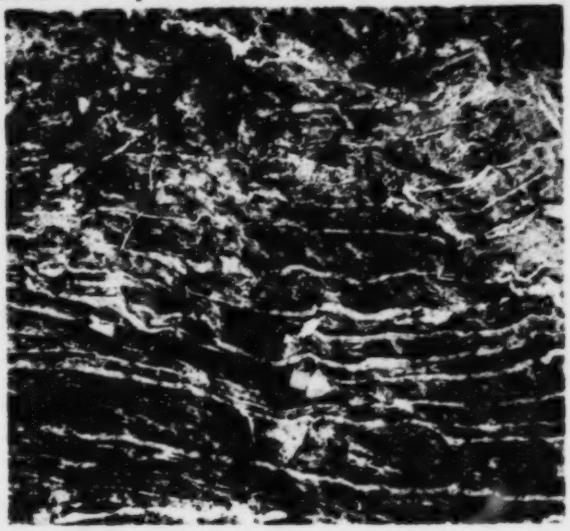


Plate 6: ***Slate containing thin, fine grained sandstone beds (unit 5).***

Southern Migmatite - Granitoid Terrane (Units 6-9)

The area south and southeast of the Bay du Nord Group is underlain by migmatite (Unit 6) and foliated granitoids (Units Unit 2, it is not included in the Bay du Nord Group since it is surrounded by granite and its exact relationship with the group is equivocal.

Unit 6 occurs in two zones that appear to form large rafts within the foliated granitoids. It consists mostly of an irregularly banded granitoid which has a wispy or streaky appearance rather than a regular gneissic fabric. Although persistent on a outcrop scale, the banding is defined in detail by discontinuous biotite-rich zones alternating with lenses of granitoid. The biotite 'streaks' range from 0.5 to 15 cm in length and are generally less than 2 mm in width; locally 0.5 cm biotite clots occur. The granitoid lenses are 1 to 4 mm wide. Disoriented, porphyroblastic muscovite and biotite are common. Metasedimentary inclusions of pelitic to psammitic composition occur locally (Plate 7). These are mostly concordant with the crude banding and have indistinct boundaries. However, in some areas, clearly outlined xenoliths occur with an internal foliation that forms various angles with the external banding in the host granitoid. Some inclusions display a regular 4 to 10 cm layering of alternating pelite and psammite that is interpreted as primary in origin. Psammitic inclusions are generally granoblastic and the biotite-rich pelitic zones locally contain feldspar porphyroblasts and profuse granitic veins. Amphibolite xenoliths are less common; rare pods and lenses of pure biotite with crystals 0.4 to 3 cm across also occur. The banding in the migmatite is locally tightly folded and regionally concordant with the main penetrative foliation in the granitoid rocks.

Plate 7: *Distinct and indistinct amphibolite and pelite inclusions in irregularly banded migmatite (unit 6).*

Unit 7 is a coarse grained biotite granite that intrudes the Bay du Nord Group and outcrops in a small area along Grey River on the western boundary of the map area. It is characterized by large feldspar phenocrysts that are 2 to 6 cm long in a biotite-rich, coarse grained groundmass. Both potassium feldspar and plagioclase form megacrysts; minor hornblende and sphene also occur. Locally, fine grained diorite and/or gabbro form mafic clots, interpreted as cognate inclusions, that are 1 to 20 cm across and have a round or elliptical outline.

Unit 7 is not penetratively foliated in its northern exposures, except for minor anastomosing 1 to 50 cm wide shear zones, within which the granite is reduced to mylonite. These shear zones increase in width and profusion toward the south where they are up to 8 m wide and regularly oriented, parallel to the regional east-west foliation. Away from the shear zones the granite is progressively foliated, developing into protomylonite that gradually merges into a mylonite zone along the granite's southern boundary (Plate 8).

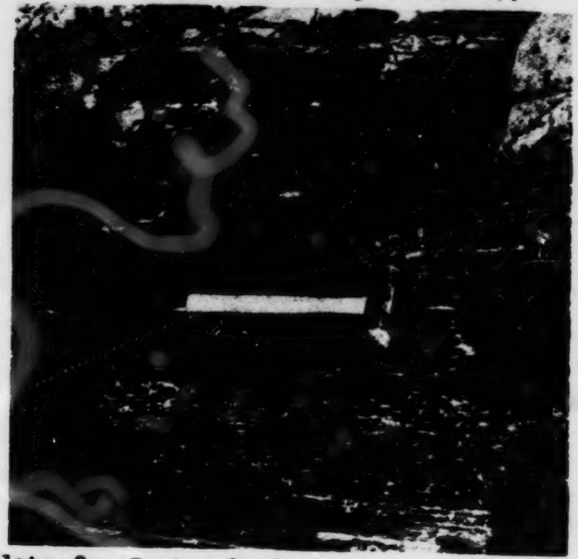


Plate 8: *Protomylonite and mylonite from shear zone in unit 7.*

Unit 8 is a medium to coarse grained, equigranular to porphyritic granite that forms the largest granitoid area in the southern terrain. It intrudes the Bay du Nord Group along the granite's northern boundary and encloses the large rafts of Unit 6 migmatite; dikes of equigranular biotite granite are common in Units 2 and 6. The relationship of Unit 8 to Unit 7 is unclear since the two are separated by a mylonite zone. However, fine grained, biotite granite dikes that intrude Unit 7 may be related to Unit 8.

The porphyritic variety of Unit 8 contains pink and white feldspar phenocrysts that are 0.5 to 3 cm long with most around 1.5 cm. Rarely, there are phenocrysts up to 5 cm long. The change from equigranular to porphyritic granite is diffuse, and is marked by a gradual increase in phenocryst content. The distribution of the porphyritic variety is also irregular; even the mostly equigranular material has isolated phenocrysts scattered throughout. Overall, biotite is less profuse than in Unit 7 although small areas of biotite-rich granite, where the mica is concentrated in patches along the foliation planes, do occur. Locally a regular layering is developed in the granite, defined by variations in the amount of biotite,feldspar phenocrysts and grain size, similar to layering in the McCallum granite

(Blackwood, 1983) to the southeast. This layering is generally concordant with the tectonic fabric.

The regional foliation in Unit 8 varies from weakly to strongly developed and is mostly defined by oriented biotite. The fabric has a distinct cataclastic component near the contact with the Bay du Nord Group west of Salmon River. Foliated granite also grades into protomylonite adjacent to and within mylonite zones east of Salmon River. The granite is also the protolith for mylonite and minor ultramylonite within the shear zones. In one area south of Grey River, foliated equigranular biotite granite is intruded by relatively unfoliated equigranular biotite granite, suggesting that Unit 8 was intruded synkinematically, with respect to the main regional deformation. A later, gently dipping fracture cleavage is also locally developed in the granite.

Unit 9 forms a small area of pink weathering, fine grained, equigranular, minor-biotite granite south of Grey River on the western border of the map area. Rare muscovite also occurs. Included within this area is a zone of quartz-feldspar-biotite porphyry that is presumably related to the fine grained granite. A moderate biotite alignment is developed in the granite as well as a local fracture cleavage. Veins of this composition are common throughout Units 6 and 8.

North Bay Granite (Units 10 and 11)

The northern and east-central portion of the map area is underlain by granitic rocks that form part of the North Bay Granite (Jewell, 1939), a large intrusive body that extends to the north and east (Dickson and Delaney, *this volume;* Dickson and Tomlin, 1983). Within the map area, the granite intrudes the Bay du Nord Group and is divisible into two phases.

Unit 10 is a biotite-rich phase that occurs along the contact with Unit 1 of the Bay du Nord Group and locally contains large rafts of metasedimentary rocks. It is medium to coarse grained and varies gradationally from equigranular to porphyritic granite, with the latter texture predominating. Feldspar phenocrysts are both pink and white and range from 0.5 to 6 cm in length with most between 1 and 3 cm. Some of the plagioclase phenocrysts are zoned. Minor, possibly secondary, fine grained muscovite occurs; disseminated pyrite was noted in some eastern exposures. Biotite is generally disoriented but weak to moderate alignments do occur. Locally a fracture cleavage is developed.

Unit 11 is a two-mica phase of the North Bay Granite, which generally, occurs north of Unit 10, but also forms a narrow tongue that transects Unit 10 and intrudes Unit 1 of the Bay du Nord Group at Grey River. Two small plugs of similar granite intrude Unit 1 between Grey and Salmon Rivers. Unit 11 is a medium to coarse grained granite with an equigranular to porphyritic texture. Feldspar phenocrysts are either pink or white and vary from 1 to 6 cm in length. Unit 11 contrasts with Unit 10 in that it has less biotite and variable amounts of muscovite. Generally the biotite exceeds muscovite but locally muscovite is more abundant. Commonly muscovite is coarser grained than biotite, forming conspicuous 2 to 4 mm flakes; at one locality, muscovite crystals are approximately 1 cm across. Rare garnets also occur. Unit 11 is unfoliated except for a locally developed fracture cleavage. Two-mica garnetiferous pegmatites and aplites of composition similar to Unit 11 intrude Units 1, 10 and 11.

Structure and Metamorphism

The Bay du Nord Group is overprinted by a fine penetrative foliation, (S_1) that developed during the first regional deformation (D_1) of the area. This fabric is axial planar to second order, isoclinal F_1 similar folds; consequently it is generally coplanar with bedding in the Bay du Nord Group. Although, F_1 folds on F_2 fold limbs must have undergone further tightening during the second deformation, isoclinal F_1 folds in F_2 fold hinges indicate the original isoclinal nature of these early structures (Plate 9).

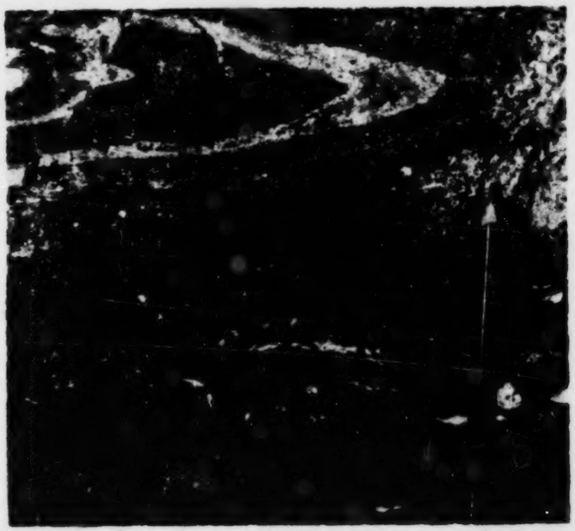


Plate 9: *S_2 strain-slip cleavage (parallel to pencil) overprints both limbs of a recumbent isoclinal F_1 fold in the hinge zone of the major F_2 structure.*

The main foliation in the southern granitoid terrain is regionally concordant with that in the Bay du Nord Group and can be shown to be a D_1 structure. Veins of equigranular granite (Unit 8) that intrude the group show the first fabric as do garnetiferous leucogranite veins common to both. These leucogranite veins commonly define F_1 folds that have both limbs overprinted by the subsequent D_2 fabric. The mostly penetrative biotite orientation in Unit 8 granite is generally subparallel to layering in that pluton and is locally axial planar to tight folds of the layering. The fabric can also be traced into Unit 6 migmatites where it is approximately parallel to the crude banding or axial planar to folds of the banding and partially assimilated inclusions.

The D_1 foliation in granite of Units 7 and 8 locally intensifies and merges into two narrow mylonite zones. The one along the southern boundary of Unit 7 at Grey River is approximately 0.25 km wide and is continuous to the west for some several kilometres (O'Brien and Tomlin, *this volume*). Its eastward trace appears truncated by Unit 8 granite although the development of a moderate cataclastic fabric along the northern boundary of Unit 8 with the Bay du Nord Group may represent a continuation of this zone of shearing. A second mylonite zone, 0.2 to 0.6 km wide, is developed in Unit 8 in the southeast. It clearly is a continuation from the southeast of the Dragon Bay Fault zone (Blackwood, 1983); within the southeastern corner of the map area it occurs as two subparallel zones, separated by a thin wedge of foliated biotite granite of Unit 8. The northern zone narrows westward for 2.5 km, where it ends in moderately foliated biotite granite. The southern zone is continuous to Salmon River where it becomes coincident with the contact between Unit 6 migmatite and Unit 8 granite. At that point it ceases to be a clearly definable shear zone in homogeneous granite and its westward trace is lost. However, shearing probably continued preferentially along the contact between Units 6 and 8, resulting in a less obvious zone of mylonitization.

Unit 8 granite is interpreted to be synkinematic with respect to the first deformation. It locally appears to truncate D_1 mylonite zones, e.g. east of Grey River, and has mylonite zones developed within it. In the latter case, a distinct zone of mylonite was observed along strike to narrow and terminate within the granite, e.g. southeast corner of the map area. These relationships suggest diachronous intrusion of Unit 8 granite into an area of active cataclastic deformation. The synkinematic nature of the granite is also indicated elsewhere where a strongly foliated phase of the pluton is intruded by a later, less deformed phase.

The original attitude of D_1 structures is not readily determinable in the map area. Southeastwards, in the Facheux Bay map area (Blackwood, 1983), large scale F_1 folds and associated second order folds are demonstrably overturned towards the south. A similar orientation is suggested for the Dolland Brook area. A model of initial recumbent folding is supported by the occurrence of overturned beds with a shallower S_1 cleavage in the core of the large scale, upright F_2 syncline. Thus, probable large scale, recumbent, F_1 folds, generally overturned toward the south, are interpreted to have developed during the first deformation (Figure 2). The Bay du Nord Group within the map area would thus represent the normal limb of such a first order recumbent fold since the lithostratigraphic units are upward facing; local overturning is due to small scale, second order F_1 folds.

The grade of metamorphism associated with the first deformation in the Bay du Nord Group varies from greenschist to upper amphibolite facies, depending upon proximity to the southern synkinematic granitoid terrain. Within the core of the F_2 syncline, S_1 is a phyllitic or slaty cleavage. The metamorphic grade increases toward the south, which is interpreted as structurally downward; this is first indicated by the occurrence of porphyroblastic muscovite in sandstones of Unit 4. Adjacent to Unit 8 foliated granite, fine grained biotite appears on S_1 fabric planes in Unit 3 felsic tuff, and fine to medium grained, biotite-muscovite schists are developed in Unit 2. Locally Unit 2 is migmatitic near the contact with Unit 8 granite. The culmination of metamorphism is represented by Unit 6 migmatites which are completely isolated within the granitoid terrain.

The second deformation (D_2) resulted in the large scale, first order F_2 fold delineated by felsic volcanic rocks (Unit 3) of the Bay du Nord Group (Figure 3). It is a mostly upright structure that plunges 20° to 30° to the west-northwest. Facing directions in the sedimentary rocks indicate that it is a syncline. Smaller, second order folds are associated with the syncline, particularly on its northern limb, and show a vergence consistent with the overall structure. Third order F_2 folds are developed throughout the Bay du Nord Group and commonly produce Type III interference patterns (Ramsay, 1967) where small scale F_1 folds are refolded; one Type I interference pattern was noted on Salmon River.

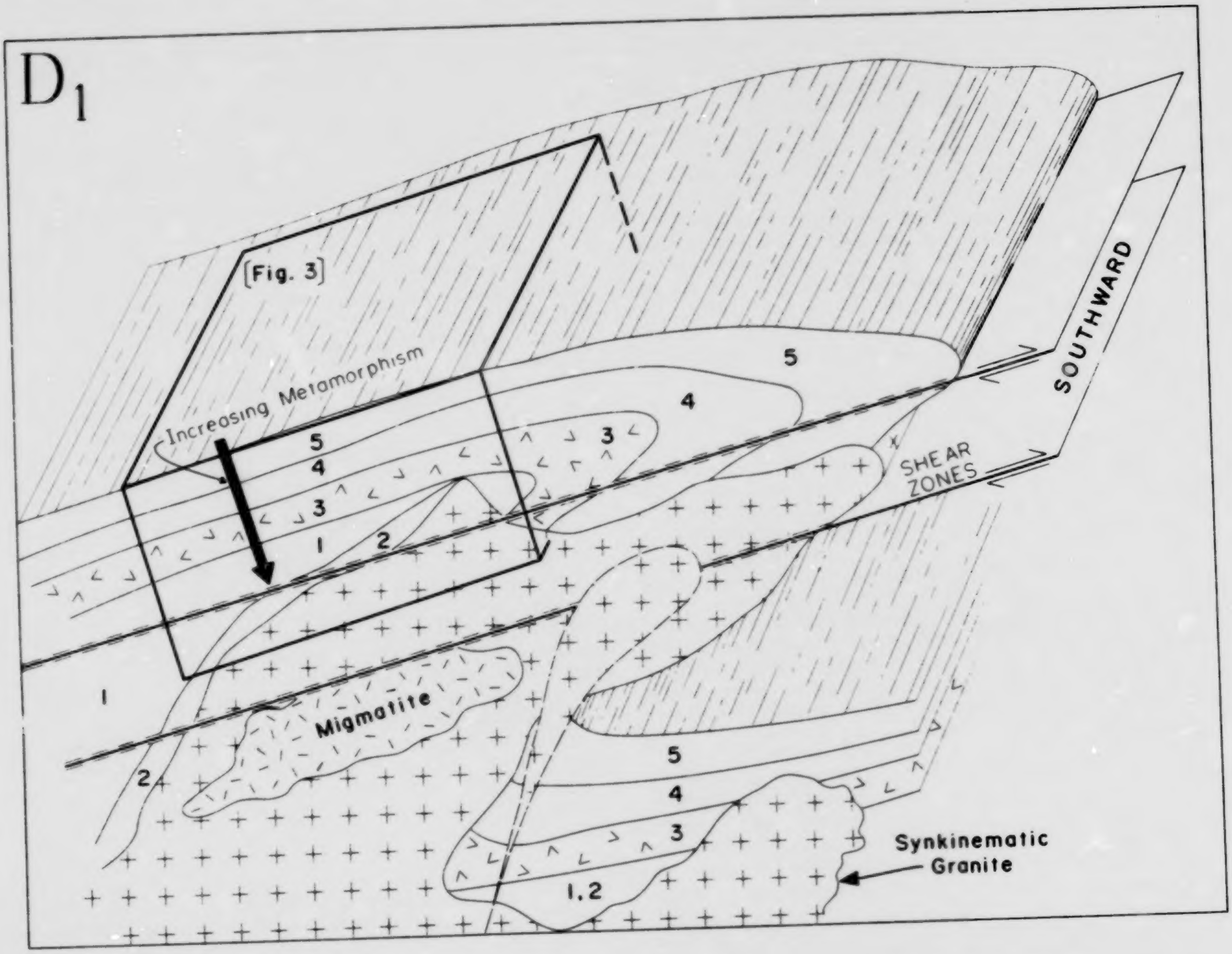


Figure 2: *An interpretive diagram showing the style and orientation of D_1 structures and their relationship to synkinematic granite.*

A variably developed strain-slip or crenulation cleavage (S_2) is commonly axial planar to the small scale F_2 folds and in a regional way to the large scale structure. It locally transposes the first schistosity and primary laminations in rocks of pelitic composition and forms a fracture cleavage in some areas within the felsic volcanics. Within the core of the syncline, the strain slip cleavage is variably oriented in Unit 5 slates, suggesting an inhomogeneous D_2 stress field.

The intrusion of the North Bay Granite (Units 10 and 11) occurred after the first deformation and during the second; it may have contributed to the shortening that resulted in the F_2 folds. Within the granite's aureole, a profusion of biotite, garnet, andalusite and hornblende porphyroblasts overprint the penetrative S_1 foliation in pelite and semipelite.

Mimetically recrystallized biotite and muscovite are developed on the S_1 fabric planes and become coarser grained with proximity to the North Bay Granite. Granoblastic recrystallization textures dominate in the quartzofeldspathic rocks. The S_2 strain-slip cleavage postdates the main episode of recrystallization within the granite's aureole and generally shows no new mineral growth along its cleavage traces. However, locally within the aureole, fine grained biotite developed along S_2 indicating the synkinematic relationship between the North Bay Granite and D_2. Weak biotite alignments and a coarse

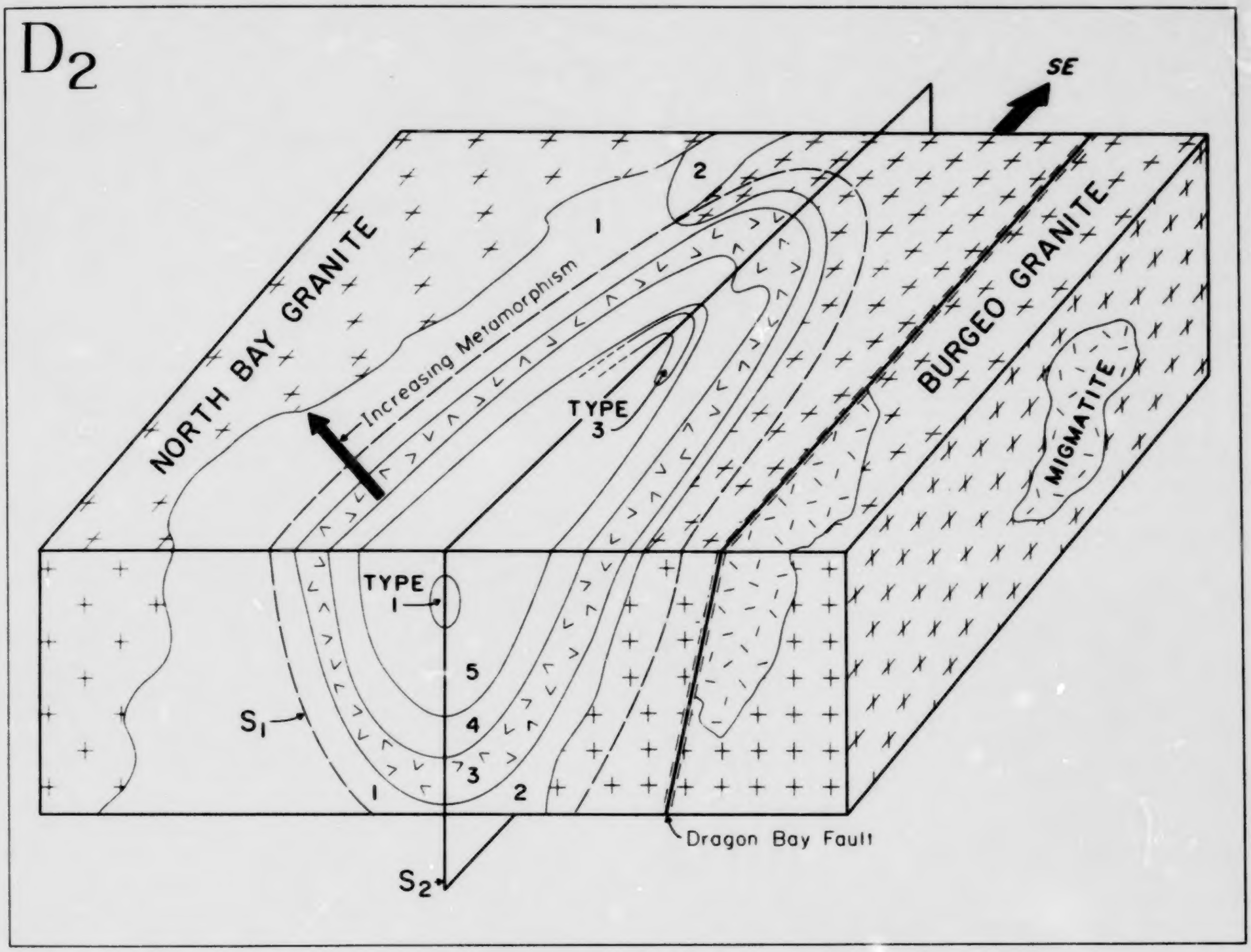


Figure 3: *A representative diagram of D_2 structures showing how the large scale F_2 fold controls the disposition and orientation of rock units and D_1 structures in the Dolland Brook map area.*

coarse fracture cleavage in the granite may also be related to the strain-slip fabric in the country rocks.

Two steeply dipping faults occur on either side of the F_2 fold hinge. Units 2 and 3 are demonstrably displaced by the southern fault; the northern one parallels the boundary between Unit 3 volcanics and Unit 8 granite. Both faults continue southeastward into the granite which is locally brecciated and chloritized within the fault zones. These faults may be related to the F_2 folding.

Mineralization

A number of scheelite occurrences were shown on the Buchans Mining Company maps (Scott and Conn, 1950) and on Smyth's (1979) compilation map. Although not confirmed during this study, their approximate locations are given on Figure 1. Most are associated with the contact between the North Bay Granite and the Bay du Nord Group and presumably occur in granite dikes that cut the metasedimentary rocks. These could be a significant indication of the Sn-W potential of the North Bay Granite and of possible uranium mineralization; O'Brien and Tomlin *(this volume)* reported anomalous radioactivity associated with scheelite-bearing granite in the adjacent White Bear River (11P/14) map area. Disseminated pyrite was found in minor two-mica granite included in Unit 10 biotite granite west of Salmon River. Pyrite and minor chalcopyrite also occur in metasedimentary xenoliths in Unit 10 granite on Salmon River.

All of the mineral occurrences found in the Bay du Nord Group during this study were of pyrite. Fine grained disseminated pyrite is common in the felsic tuffs of Unit 3, locally producing gossan zones, e.g. just east of Grey River. Pyritiferous, rusty weathering felsic tuff is infolded with black graphitic pyritiferous pelite west of Salmon River. Scott and Conn (1950) indicated arsenopyrite and scheelite in Unit 3 volcanics east of Salmon River. Pyrite is also common in Unit 5 slates and siltstones; Smyth (1979) indicated pyrrhotite in this unit on Grey River. Thus the best potential for base metal mineralization lies in the distal submarine felsic volcanics of the Bay du Nord Group and the associated graphitic pelites and slates. The restriction of volcanic breccia and/or agglomerate to the area east of Salmon River may suggest the proximity of a feeder vent.

Conclusion

Part of the Bay du Nord Group is interpreted to represent a turbidite sequence consisting of thin and thick bedded turbidites, resedimented conglomerate and pebbly sandstone. Felsic volcanic rocks form a distal facies within the sedimentary sequence. The first deformation of the group resulted in recumbent isoclinal folds that were probably overturned towards the south. These structures are presumed to have been related to large scale, first order folds similar to those in the Facheux Bay area. The upward facing direction of stratigraphic units in the Bay du Nord Group suggests that these rocks were confined to the normal limb of such a large scale recumbent fold. Metamorphism increased during D_1 towards synkinematic granites, culminating in partial melting and granite injection of the deeper levels of the deforming pile (Figure 2). Narrow D_1 cataclastic zones may mark thrust faults that developed during this period of folding and granite intrusion. Post-D_1 granite intrusion and upright F_2 folding resulted in the steepening of D_1 structural elements and produced the present outcrop pattern in the Dolland Brook area (Figure 3).

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Note: Unpublished reports are followed by numbers in square brackets, which refer to Mineral Development Division files.

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R. Frank Blackwood

GEOLOGY OF THE COLD SPRING POND MAP AREA (West Part) 12A/1, NEWFOUNDLAND

by

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Abstract

The western half of the Cold Spring Pond area was mapped during 1983. Parts of it have previously been explored by mining companies and all of it has been included in regional geological and geochemical surveys.

Ultramafic rocks and a volcanic-sedimentary sequence form the westward extension of the Lower to Middle Ordovician Baie d'Espoir Group and its supposed ophiolitic basement. These rocks are in fault contact with quartzite and pelite similar to the Lower to Middle Ordovician Spruce Brook unit outcropping to the northeast. The quartzite and pelite have associated felsic volcanic rocks and conglomerate and are cut by mafic dikes.

An isolated outcrop of sandstone, shale and conglomerate in the southwest of the area resembles Silurian rocks in north-central Newfoundland.

An area of high grade metasedimentary, migmatitic and granitic rocks is mainly in fault contact with older units, but does contain xenoliths of ultramafic and Baie d'Espoir Group rock types. Younger granites which are intrusive into the Baie d'Espoir Group, the Spruce Brook unit and the migmatites, are all deformed, some of them intensely. A large intrusion of gabbro and diorite is only locally deformed and was probably unaffected by major fault systems. The major intrusions are most likely to be Devonian.

Minor sulfide mineralization has been found in felsic volcanic rocks of the Baie d'Espoir Group and the Spruce Brook unit.

Introduction

The Cold Spring Pond area is located about 40 km northwest of St. Alban's. The eastern part of it is accessible from the road which links St. Alban's to the Godaleich Pond hydroelectricity station and the northwest corner can be reached from Millertown by way of the road to Ebbegumbaeg dam and Meelpaeg Lake. The remainder is only accessible by aircraft.

The eastern part of the area was mapped at 1:20,000 and 1:50,000 scales in previous years by Swinden and Collins (1982) and Colman-Sadd (1983). The accompanying map (Figure 1) shows the whole NTS area, but only units that occur in the western part and have been the subject of mapping during 1983 are discussed below. The boundary between the 1983 work and the earlier work coincides with a line running south through Cold Spring Pond and, south of the gabbro intrusion, with the easterly extent of the Spruce Brook unit. The 1:50,000 scale geological map of the Cold Spring Pond area is available on open file (Colman-Sadd and Swinden, 1983).

Previous work in the western part of the area consists of detailed surveys by mining companies and regional surveys by government agencies. Phendler (1950, 1951) mapped the northwestern quadrant for the Buchans Mining Company. Sander and Heshka (1970) did geological, geophysical and geochemical work north of Cold Spring Pond as part of a larger exploration project by the Hansa Syndicate in the southern part of the Great Burnt Lake volcanic belt (Colman-Sadd and Swinden, 1982). Anomalies identified during this survey were subsequently staked by Consolidated Morrison Exploration, and further geological and geophysical work was done in a joint venture with Rio Tinto Canadian Exploration (Bucknell et al., 1976). Two holes were drilled northwest of Cold Spring Pond as part of this program.

Two regional surveys have included the Cold Spring Pond area. It forms part of the Red Indian Lake (east half) 1:250,000 scale geology map of Williams (1970), published by the Geological Survey of Canada. It was also included in a lake sediment geochemistry survey conducted by the Newfoundland

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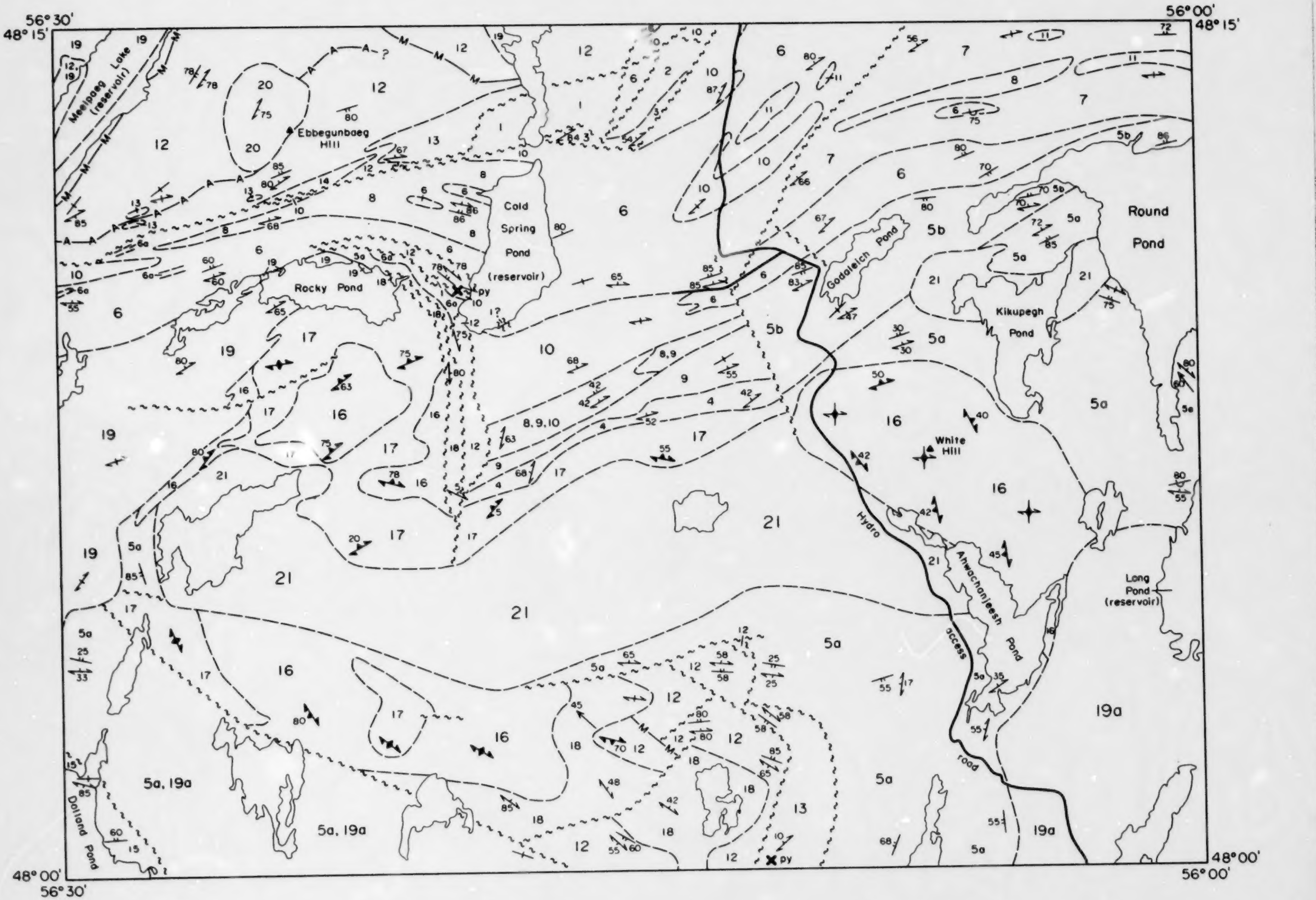
Contribution to the Canada-Newfoundland co-operative minerals program 1982-84. Project funded by the Newfoundland Department of Mines and Energy.


56°30'
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56°00'
Meelpaeg Lake (reservoir)
Ebbegunbaeg Hill
Cold Spring Pond (reservoir)
Rocky Pond
Godaleich Pond
Kikupegh Pond
Round Pond
White Hill
Hydro access road
Ahwachanjeesh Pond
Long Pond (reservoir)
Dolland Pond
py
py

Figure 1: *Geological map of the Cold Spring Pond area (12A/1), simplified from Colman-Sadd and Swinden (1983). Only the western part of the area is described in this report.*

LEGEND

DEVONIAN or older

21 *Gabbro, diorite and minor granodiorite.*

20 *Medium to fine grained, equigranular, lineated or foliated biotite granite.*

19 *Equigranular to porphyritic, medium to coarse grained, moderately foliated biotite or biotite-muscovite granite. Includes* **North Bay Granite (19a).**

18 *Strongly foliated, megacrystic biotite granite.*

17 *Diffusely banded, medium to fine grained muscovite-biotite granite, with abundant xenoliths of schist and psammite.*

16 *Well foliated, medium to coarse grained migmatite, with schlieren structure; locally includes nonmigmatitic sillimanite schist.*

SILURIAN (?)

15 *Thin to medium bedded, moderately cleaved, dark greenish gray sandstone and shale.*

LOWER to MIDDLE ORDOVICIAN

Baie d'Espoir Group *(Units 4-11) (no stratigraphic order implied by sequence)*

North Steady Pond Formation *and related units (Units 6-11).*

11 *Mafic pillow lava, massive basalt, pillow breccia. Includes considerable fine grained chloritic tuff and lesser fine grained sediments.*

10 *Silicic pyroclastic rocks: dark green, gray or black siliceous tuff with abundant quartz crystals and local concentrations of feldspar crystals and/or lithic fragments; locally associated with limestone.*

9 *Dark green, thinly bedded phyllite.*

8 *Conglomerate: polymictic, unstratified to poorly stratified boulder and pebble conglomerate; commonly matrix-supported and poorly sorted.*

7 *Silicic tuff and reworked tuff, quartz and feldspar crystal tuff and crystal-lithic tuff; commonly unstratified but locally shows evidence of reworking.*

6 *Sedimentary rocks: includes gray to green, thick to thin bedded arkosic sandstone, siltstone and laminated phyllite, with local black graphitic argillite* **(6a).**

Salmon River Dam Formation

5 *Dark purplish gray siltstone and very fine grained sandstone with minor calc-silicate, pelitic and quartzitic beds;* **5a**, *mainly medium to thick bedded;* **5b**, *thin bedded.*

4 *Psammitic schist with quartz and granite sweats.*

Spruce Brook *and related units (Units 12-14) (no stratigraphic order implied by sequence).*

14 *Conglomerate composed mainly of quartzite clasts.*

13 *Felsic crystal tuff and subvolcanic(?) granite.*

12 *Interbedded quartzite and pelite; metamorphic grade varies from greenschist facies to migmatite; ----A---A, first appearance of andalusite; ----M----M, beginning of melting.*

CAMBRIAN to LOWER ORDOVICIAN

3 *Basalt, pillowed to massive flows, commonly variolitic; pillow breccia; minor tuff.*

2 *Coarse to medium grained gabbro and trondhjemite, with minor pyroxenite.*

1 *Peridotite, fine grained, commonly with pyroxene phenocrysts and disseminated chromite.*

Department of Mines and Energy (Butler and Davenport, 1978).

The geology of the area is most easily discussed in terms of five tectonostratigraphic components:

(1) Ophiolitic rocks (Units 1 to 3) and volcanic and sedimentary rocks of the Baie d'Espoir Group (Units 4 to 11). These rocks probably span the time interval from Cambrian to Middle Ordovician.

(2) Sedimentary and volcanic rocks of the Spruce Brook (?) and related units (Units 12 to 14) of probable Early to Middle Ordovician age.

(3) Sedimentary rocks at Dolland Pond, possibly of Silurian age (Unit 15).

(4) Granite, migmatite and associated high grade metamorphic rocks. The time of intrusion was probably Devonian (Units 16 to 20).

(5) Gabbro/diorite, possibly of Devonian age (Unit 21).

The separation of components (1) and (2), despite their similar ages, results from a structural interpretation derived from work in the Burnt Hill (2D/5), Miguels Lake (2D/12) and Great Burnt Lake (12A/8) areas. The interpretation, outlined by Colman-Sadd and Swinden (1982), proposes that rocks of component (1), representing typical Dunnage Zone sequences, occur as an allochthonous sheet on rocks of component (2) (Spruce Brook and related units) and probably also on the less mobilized parts of component (4) (granites and migmatites). The map pattern in the Cold Spring Pond area is consistent with this interpretation but does not require it.

General Geology

Component 1: Ophiolitic Rocks and the Baie d'Espoir Group (Units 1-11)

Ophiolitic rocks west of Cold Spring Pond consist exclusively of peridotite altered principally to serpentine and magnesite. There are three outcrop areas.

In the northern outcrop, peridotite is associated with other ophiolitic rock types northeast of Cold Spring Pond (Swinden and Collins, 1982). Northwest of the pond, in the part of the outcrop mapped during 1983, only four exposures have been found. Three of these consist of massive serpentinized peridotite with disseminated crystals of chromite and only minor fracturing. The fourth is composed, in large part, of magnesite and talc, and consists of massive blocks of altered peridotite in a well foliated matrix. The contacts of the peridotite body are presumed to have been faulted. The southern contact zone is probably represented by an exposure of brecciated graphitic slate in a stockwork of quartz on the shore of the pond north of Cold Spring Pond. Boulders of this breccia can be traced westward towards a strong topographic lineament that is interpreted as a fault between the Baie d'Espoir Group of Component 1 and the Spruce Brook unit of Component 2. The northern boundary between the peridotite and felsic crystal tuff is unexposed, but presumed to be faulted. It was probably intersected by diamond drill hole GBL2 of Bucknell et al. (1976). The hole was collared in felsic crystal tuff and drilled at an angle of 45° to the south. It penetrated 90 feet (28 m) of tuff and below that continued in interlayered graphitic shale and talc schist. It bottomed at 543 feet (167 m) in a 170 feet (52 m) layer of talc schist.

The central outcrop of ophiolitic rocks consists of a narrow zone exposed in the brook between Rocky and Cold Spring Ponds. An extension of this zone may be present on the southeast shore of Cold Spring Pond where ultramafic boulders are common but no *in situ* exposures have been observed. In Rocky Pond brook, the peridotite is mostly sheared to form a talc-serpentine schist, but in places where the ultramafic zone widens there are also exposures of more massive peridotite. Exposed contacts of the peridotite with the surrounding rocks reveal that not only are its boundaries faulted, but also that it is emplaced along a significant structural discontinuity between the rocks on either side of it. Exposures to the north of the peridotite are typical of the Spruce Brook unit (Component 2) and those to the south are formed of Baie d'Espoir Group rock types (Component 1).

The southern outcrop of ophiolitic rocks occurs to the southwest of Cold Spring Pond and is formed of a single exposure of massive serpentinized peridotite in excess of 150 m in diameter (Plate 1). The peridotite is entirely surrounded by granite and migmatite exposures and appears to form a xenolith within these rocks. The contacts are not exposed, but the peridotite contains porphyroblasts of a white phyllosilicate and is cut by coarse grained veins of the same phyllosilicate with probable tremolite and a variety of other minerals. The veining and porphyroblast growth probably indicate postserpentinization progressive metamorphism, which could have been achieved during migmatization of the country rocks. The original emplacement

Plate 1: *Peridotite exposed southwest of Cold Spring Pond and entirely surrounded by exposures of migmatitic gneiss. Man in left center for scale.*

of the peridotite before metamorphism may well have been along "cold" faults as in the cases of the two peridotite bodies to the north, but these contacts are now presumed to have been completely remobilized.

Rocks of Units 4 to 11 are here provisionally assigned to the Salmon River Dam and North Steady Pond Formations of the Baie d'Espoir Group, although it should be noted that a revision of stratigraphic nomenclature is presently being prepared by H.S. Swinden in a Mineral Development Division Report, and that this will propose the reassignment of some of these units. The Baie d'Espoir Group, in the Cold Spring Pond area, is thought to have been deposited, at least in part, on oceanic crust, represented by the ophiolitic rocks of Units 1 to 3. All the contacts are now faulted and the supposed relationship is based on the regional geology of the Central Mobile Belt, as discussed by Colman-Sadd and Swinden (1982). The lithologies of the Baie d'Espoir Group units are briefly described in the legend; the following paragraphs are mainly concerned with structural and stratigraphic relationships.

The Salmon River Dam Formation (Unit 5a) occurs as medium to thick bedded purplish sandstone. Southwest of Ahwachenjeesh Pond exposures at the western edge of the formation's extent contain metamorphic biotite and are separated from the andalusite- and sillimanite-bearing Spruce Brook unit by marked topographic lineaments. In several localities the lineaments are exposed as steeply dipping fault zones. Northeast of Dolland Pond, a few scattered exposures of the formation are present and most of these are intruded by sills and dikes of muscovite-biotite granite, apparently related to the North Bay Granite. Between Cold Spring and Rocky Ponds, the Salmon River Dam Formation may pass conformably eastward into graphitic argillite (Unit 6a), but is faulted on the west against sheared and mylonitized biotite granite (Unit 18). Nebulous screens and xenoliths of rock types typical of the Salmon River Dam Formation occur as unseparated parts of the granite and migmatite terranes of Units 16 and 17, but they do not appear to have formed the principal protolith of these units.

Rocks of the North Steady Pond Formation, in the west part of the map area, are restricted to a belt extending west from Cold Spring Pond along the north side of Rocky Pond. They consist of various sedimentary rock types with intercalated lenses of quartz-feldspar crystal tuff. The tuff (Unit 10) occurs at three localities. Between Rocky and Cold Spring Ponds it is light gray and locally impregnated with quartz veins and segregations that contain disseminated pyrite. At least two beds of tuff are present, separated by graphitic slate and limestone. A similar light gray rock occurs at the west edge of the area in a lens that appears to be about 500 m thick, although exposure is not sufficiently good to show whether the tuff is actually interbedded with other rock types. Black, poorly cleaved crystal tuff, similar to rocks found between Cold Spring and Godaleich Ponds, occurs in a small exposure at the bottom of the valley marking the presumed fault between components 1 and 2. The absence of this rock type immediately along strike and its presence in a possible fault zone suggests that it may have been emplaced as a fault slice.

Sedimentary rocks of the North Steady Pond Formation are mainly green-gray arkosic sandstone (Unit 6) and conglomerate (unit 8). Identifiable clasts consist of sedimentary rocks, felsic and mafic volcanics, and granite, together with monomineralic clasts derived from these rock types. The sandstone commonly has thin interbeds of green-gray pelite and also contains thick beds of strongly folded black graphitic argillite (unit 6a). Limestone has been found at one locality between Rocky Pond and Cold Spring Pond. It is a light brown quartzose calcarenite and occurs in a single massive lens about 2 m thick, enclosed between beds of felsic crystal tuff and graphitic slate.

Rocks of Component 1 were subject to one regional deformation, which formed a penetrative cleavage and isoclinal folds. A second deformation is indicated in many exposures by crenulation of the first cleavage, and this deformation may have been responsible for some of the faulting. Metamorphism is generally in the greenschist facies. Exceptions are where peridotite and rocks of the Salmon River Dam Formation are present as xenoliths and screens in the migmatitic rocks of Units 16 and 17. Exposures of the Salmon River Dam Formation that are intruded by granite northeast of Dolland Pond may also be at a higher grade, but the psammitic composition of the rock prevents easy identification of metamorphic grade.

Component 2: Spruce Brook (?) and Related Units (Units 12-14)

Rocks provisionally included in the Spruce Brook unit in the Cold Spring Pond area consist mainly of interbedded quartzite and pelite at various grades of metamorphism (Plate 2). They are similar to rocks exposed in the Burnt Hill (2D/5), Miguels Lake (2D/12) and Great Burnt Lake (12A/8) areas (Colman-Sadd and Swinden, 1982), which contain Lower to Middle Ordovician fossils. The unit outcrops in four separate parts of the Cold Spring Pond area.

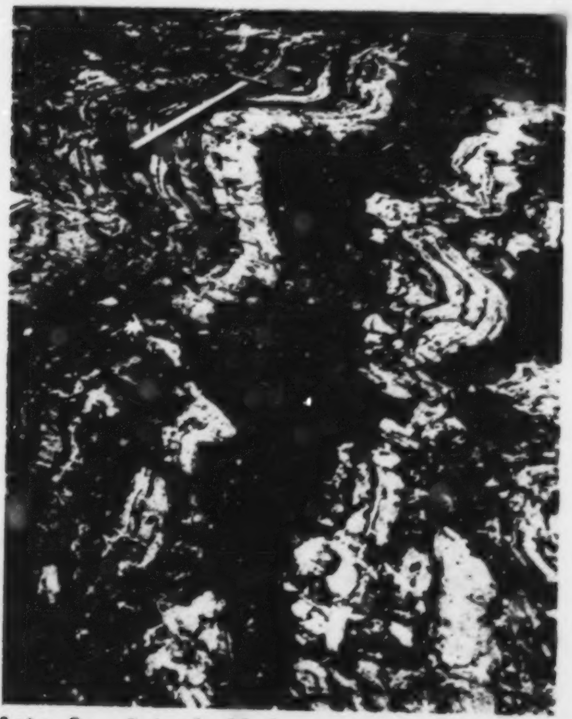

Plate 2: *Interbedded quartzite and pelite of the Spruce Brook Formation near Meelpaeg Lake. An isoclinal, first deformation fold closes near the bottom of the photograph, and is refolded by open second deformation folds.*

In the northern outcrop area around Ebbegunbaeg Hill, two additional lithologic types are present. Quartz-feldspar crystal tuff (Unit 13) occurs as lenses in the quartzite and pelite. The lenses are sharply bounded and do not appear to have shed detritus into the neighboring sediments. They are particularly interesting because the Spruce Brook unit has hitherto been characterized as devoid of volcanic rocks (Colman-Sadd and Swinden, 1982). Conglomerate (Unit 14) occurs in two exposures just north of the contact with the Baie d'Espoir Group and, in contrast to the conglomerate of Unit 8, consists almost entirely of quartzite clasts. The clasts have apparently been derived from quartzite beds of the Spruce Brook unit. A similar conglomerate has been found by Dickson and Delaney (1984, in this volume) in the neighboring Wolf Mountain area (12A/2) to the west. A further feature of the northern outcrop area is the presence of mafic dikes which in the high grade rocks at the edge of Meelpaeg Lake are represented by sheets of amphibolite. The northern outcrop area is considered to be faulted against the Baie d'Espoir Group for the following reasons: (1) part of the contact is occupied by ultramafic rocks, (2) a marked topographic lineament extends west from the ultramafic outcrop, and (3) there is an inconsistency of units along the contact suggesting tectonic truncation. Metamorphism in the northern area varies from greenschist facies up to migmatite and shows a general increase in grade towards the granite of Unit 19. Isograds that can be easily mapped in the field are those at the first appearance of andalusite and at the inversion of andalusite to sillimanite (Colman-Sadd and Swinden, 1983).

The outcrop area just west of Cold Spring Pond has an exposed fault contact with ultramafic rocks on its south boundary, but its north boundary is unexposed. The outcrop area south of Cold Spring Pond cuts across the strike of the Baie d'Espoir Group rocks to the east and is bounded to the west by sheared and mylonitized granite. The unit in both areas is metamorphosed in the greenschist facies.

At the southern edge of the map area the Spruce Brook unit is in exposed fault contact with the Salmon River Dam Formation, and has probably been intruded by foliated granite of Unit 18. In this part of the area, it consists entirely of quartzite and pelite containing andalusite or sillimanite, and/or migmatitic sweats.

Felsic crystal tuff and granite of Unit 13 are tentatively included in the map legend as associates of the Spruce Brook unit. The contacts however are faulted, and the tuff and granite may actually form part of the Baie d'Espoir Group. One sample of the crystal tuff was found to contain disseminations of pyrite and other undetermined sulfide minerals.

The Spruce Brook and related units have a dominant penetrative cleavage. This cleavage, however, has irregular trends that strongly suggest the presence of important large scale second deformation structures, and in several exposures a second cleavage is visible.

Component 3: Sedimentary Rocks at Dolland Pond

Several exposures of dark green sandstone and shale (Unit 15) are associated outside the Cold Spring Pond area with polymict conglomerate. The conglomerate was likened by Williams (1970) to the Silurian Goldson Formation, and the sandstone and shale bears a striking resemblance to rocks of the Silurian Botwood Group in the West Gander Rivers area (2D/11) (Blackwood, 1981; Colman-Sadd, 1982). The rocks have a single penetrative cleavage and are metamorphosed in the greenschist facies. Their contacts with the Salmon River Dam Formation are assumed to be faulted because of the relatively low metamorphic grade and the absence of granite veins.

Component 4: Granites, Migmatites and Related Rocks

Granitoid rocks of the Cold Spring Pond area fall into four groups. The oldest of these displays a continuous variation (Units 16 and 17) from sillimanite schist through migmatite (Plate 3) to fine grained granite caused by partial melting of a sedimentary protolith. The granite end-member of these two units is a rusty weathering, medium to fine grained rock, crowded with xenoliths of biotite schist and psammite (Plate 4). Locally it also contains sheets and xenoliths of the Salmon River Dam Formation and peridotite.

Strongly foliated biotite granite of Unit 18 is coarse grained and in many places megacrystic. It has intruded migmatite of Unit 16 and the Spruce Brook unit, and has been emplaced along the fault south of Cold Spring Pond as a cataclastically deformed and locally mylonitized tectonic slice. In the southern part of the area, the strong first deformation fabric was tightly folded by a second deformation (Plate 5); the outcrop pattern may reflect this period of folding.

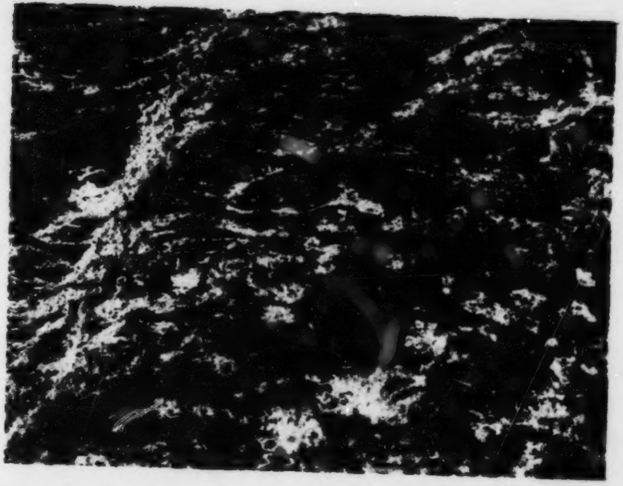

Plate 3: *Migmatized mica schist of Unit 16, northeast of Dolland Pond.*

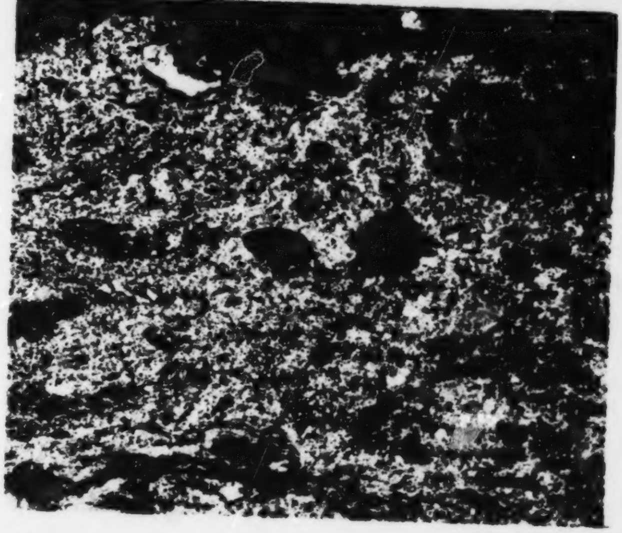

Plate 4: *Rusty weathering, fine to medium grained granite of Unit 17, south of Rocky Pond. The granite is crowded with xenoliths of psammite and sillimanite schist, and contains quartz segratations.*

Equigranular to porphyritic biotite or biotite-muscovite granite of Unit 19 forms part of the North Bay Granite batholith and associated intrusions. In contrast to granite of Unit 17, it contains few xenoliths and has sharply defined intrusive contacts. It has intruded rocks of the Baie d'Espoir Group and Spruce Brook unit, as well as the granite and migmatite of Units 16 and 17.

Biotite granite of Unit 20 is medium to fine grained, locally has quartz megacrysts, and is cut by a few quartz

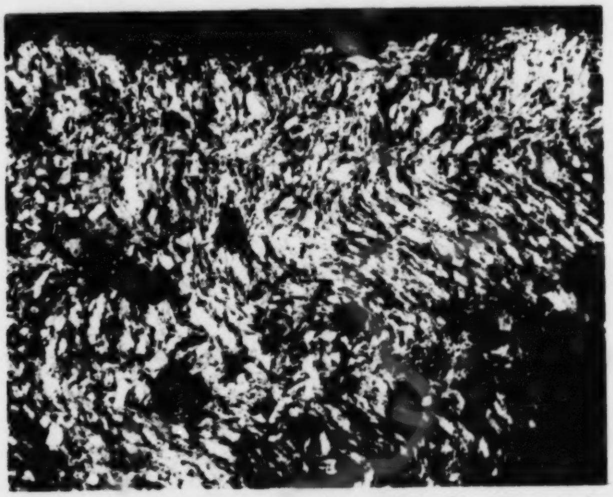

Plate 5: *Biotite granite of Unit 18, east of Dolland Pond. A strong first deformation fabric was refolded during a second deformation.*

porphyry dikes. Much of the intrusion has a strong steep lineation or foliation and it has deflected structures in the country rocks. It has not, however, had any metamorphic effect on the country rocks.

Component 5: Gabbro/Diorite

Medium grained hornblende gabbro and quartz-biotite-hornblende diorite (Unit 21) form an intrusion that cuts the Salmon River Dam Formation and the granite and migmatite of Units 16 and 17. The gabbro is only very locally foliated and the outcrop does not appear to be offset by the fault south of Cold Spring Pond. For these reasons, the time of intrusion is considered to be relatively late in the development of the geology of the area.

Mineral Potential

Sulfide mineralization has been found in felsic pyroclastic rocks of Units 10 and 13, which probably have the greatest potential for economic mineral deposits of any of the five units described in this report. The occurrence in Unit 10 is located in the brook between Rocky Pond and Cold Spring Pond, and consists of disseminated pyrite in silicified felsic tuff and in quartz veins and segregations in the tuff. The tuff layer, which is no more than 2 m thick, is interbedded with pyritiferous, black, graphitic slate (Unit 6a). In Unit 13, a single sample from near the south edge of the map area contains a 1 cm patch of fine grained sulfide minerals, including pyrite and at least one other presently unidentified mineral. No other mineralization was found at this locality.

Granite of Unit 19 has yielded no indication of mineralization within the map area, but lake sediment surveys have identified tungsten anomalies just to the south, apparently within the same intrusion (Davenport and Butler, 1982).

Acknowledgements

I thank Anthony Benoit for able assistance in the field, and Scott Swinden and Lawson Dickson for critically reading the manuscript.

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Note: Mineral Development Division file numbers, where available, are included in square brackets at end of each reference to an unpublished report.

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S.P. Colman-Sadd

GEOLOGY OF THE WHITE BEAR RIVER MAP AREA (11P/14), SOUTHERN NEWFOUNDLAND

by

S.J. O'Brien and S. Tomlin

Abstract

The White Bear River map area is situated along the northernmost part of the Hermitage Flexure of the Newfoundland Appalachians, and has components characteristic of both the Dunnage and Gander Zones of the orogen. The area's salient geological elements include a suite of ophiolitic meta-igneous rocks, with an apparently overlying metasedimentary and metavolcanic succession of presumed Ordovician age, and a post-Ordovician suite of synkinematic and late kinematic biotite granites. The stratified rocks comprise the Bay du Nord and La Poile Groups and the granitoid rocks comprise parts of the North Bay Granite and the Burgeo batholith. Younger muscovite-bearing granitoids include the Cochrane Pond granite, which intrudes the Bay du Nord Group and contains uranium, molybdenum and tungsten mineralization. The area was affected by regional post-Ordovician deformation accompanied by mid-greenschist to upper amphibolite facies metamorphism.

Introduction

The White Bear River map area (Figure 1), bounded by north latitudes 47°45' and 48°00' and west longitudes 57°00' and 57°30', is centered approximately 45 km east of the community of Burgeo, in southwestern Newfoundland. Although portions of the southern part of the area can be reached from White Bear Bay, the remainder is readily accessible only by air.

The area was extensively glaciated during the Late Wisconsinian, and evidence of this glaciation is widespread. Much of the area underlain by the Burgeo Batholith is characterized by an irregular, rugged topography with many roches moutonnees. With the exception of the resistant ophiolitic ridges near Top Pond, much of the remainder of the area forms a rolling peneplain broken by several prominent roches moutonnees.

Previous geological surveys in the area include the 1:250,000 scale mapping of Riley (1959), the reconnaissance mapping and compilation of Smyth (1979) and unpublished mapping carried out in conjunction with the exploration programs of Buchans Mining Co. (Scott and Conn, 1950) and Falconbridge Nickel Co. (Barry, 1980).

General Geology

The White Bear River area lies on the northern reentrant of the Hermitage Flexure (Williams et al., 1970) and contains geological elements of the Gander and Dunnage Zones (Williams, 1976) of the Newfoundland Appalachians. The northern segment of the area is underlain mainly by an east to east-southeast trending belt of polydeformed metasedimentary, metavolcanic and ophiolitic meta-igneous rocks, which is continuous westward with, and in part correlative to, the Ordovician La Poile and Bay du Nord Groups (Cooper, 1954; Chorlton, 1980; O'Brien, 1983). These rocks are also considered to be in part correlative with the Baie d'Espoir Group (Jewell, 1939; Colman-Sadd, 1976) to the east. The Bay du Nord and La Poile Groups in the White Bear River area, together with underlying ophiolitic rocks, are intruded in the south by syn- to late tectonic granitoids of the Burgeo batholith (Williams, 1978; O'Brien, 1983). The Bay du Nord Group is also intruded by the North Bay Granite in the northeast and by several smaller syn- to late tectonic granites that are geographically separate from the larger plutons and confined to the volcano-sedimentary belt.

Although the absolute ages of rocks in the White Bear River map area are unknown, limited isotopic data is available for some equivalent units elsewhere in southern and south-central Newfoundland. The Bay du Nord Group to the southwest has been dated isotopically at 449 ± 20 Ma (U/Pb zircon, reported in Chorlton, 1980). In the same area, the La Poile Group has been dated at 459 ± 18 Ma (Rb/Sr isochron, reported in Chorlton, 1980). Ophiolitic rocks of the Annieopsquotch Complex, possible equivalents of ophiolitic rocks in the White Bear River area, have been dated isotopically at 477 +1.3,-1.0 Ma and 481 +4.0,-1.9 Ma (U-Pb zircon) (Dunning and Krogh, 1983). The only fossil control in equivalent units elsewhere is in the Baie d'Espoir Group which contains Middle Ordovician fossils (Baird et al., 1951; Colman-Sadd, 1976).

Unit 1

The inferred base of the stratigraphic succession within the map area is an assemblage of gabbro, pyroxenite, diabase and peridotite (Unit 1), here interpreted to be of ophiolitic origin. These rocks are exposed in an elongate, 15 km^2 roof pendant in the Burgeo batholith southeast of Top Pond. The unit, disrupted by faults, consists of peridotite, pyroxenite and gabbro in the southeast, succeeded to the northwest by massive and layered gabbro and pyroxenite, and further northwestward by layered gabbro cut by rare diabase dikes. The dominant rock type of the unit is layered to locally massive, dark gray and green, medium grained equigranular gabbro. The nature of the layering within the gabbro is variable. Cumulate layering may be either coarse (ca. 10 cm), fine (1 to 10 mm), well developed or ill-defined. Locally, the layering was remobilized during metamorphism and in places the gabbros were cut by plagioclase veins and sweats. Medium to coarse grained pyroxenite occurs in association with the gabbros. The pyroxenite may occur either in separate exposures or together with gabbro; however, no clear contact relations were discernible. Brown weathering, dark green to black peridotite is in fault contact with massive gabbro to the southeast. The peridotite has either tectonic or igneous banding and is serpentinized. Fine grained diabase is rare and occurs as narrow dikes intruded parallel to the layering in gabbro (Plate 1).

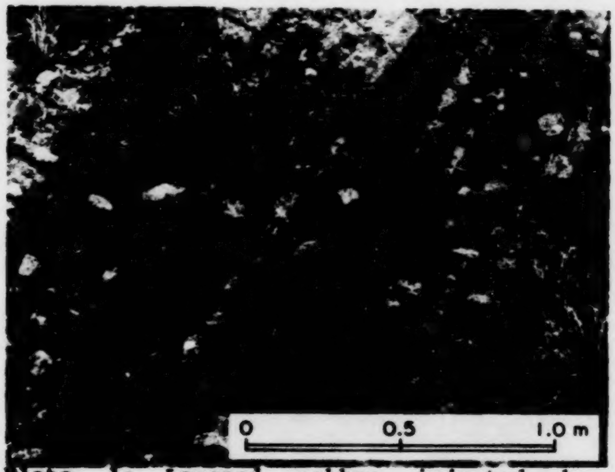

Plate 1: *Layered gabbro injected by narrow diabase dikes (Unit 1).*

BAY DU NORD GROUP (UNITS 2-6)

The name Bay du Nord Group was originally used by Dorf and Cooper (1943) and subsequently by Cooper (1954) to designate a succession of predominantly metasedimentary rocks exposed in two belts in La Poile and Garia Bays of southwestern Newfoundland. Included in the group was a sequence of clastic sediments containing Devonian plant fossils (Dorf and Cooper, 1943). Chorlton (1980) redefined the group, separating the fossiliferous succession from the remaining metavolcanics, metasediments, migmatites and amphibolites. O'Brien (1983) extended the group northeastwards, including within it the metavolcanics and metasediments that lay between the Bay d'Est and Gunflap Hills faults in the Peter Snout map area. The volcanic and sedimentary rocks exposed north of the Burgeo batholith in the White Bear River area represent the eastward continuation of the Bay du Nord Group.

In the White Bear River area, the group is tentatively divided into five lithologic units, including a lower succession of mafic and felsic volcanics (Units 2 and 3 respectively) and an upper clastic sedimentary succession of sandstone and conglomerate (Unit 4), black slate, shale and phyllite (Unit 5) and sandstone, siltstone and shale, and their metamorphic equivalents (Unit 6).

Unit 2

Unit 2 is a narrow, and laterally discontinuous, fault-bounded and repeated succession of mafic tuff, mafic tuffaceous siltstone and sandstone, and amphibolite, here tentatively included within the Bay du Nord Group. The unit is intruded by syn- to late tectonic porphyritic granite of the Burgeo batholith and is faulted against the upper metasedimentary sequences of the Bay du Nord Group. Unit 2 is not in contact with ophiolitic rocks of Unit 1 and its relationship with the felsic volcanics of the Bay du Nord Group is enigmatic.

Unit 2 is dominated by tuffaceous volcanic and volcanogenic sedimentary rocks and their metamorphic equivalents. They are either massive or schistose, and banded, laminated or without primary structure. Amphibolitized bands within the laminated tuffs may represent basic dikes or flows; more massive amphibolite is exposed in the northern parts of this unit in White Bear River.

Unit 2 may represent either the distal facies of an early, distinct episode of mafic volcanicity, or a local period of mafic volcanicity that was essentially contemporaneous with the felsic volcanism characteristic of the group.

Unit 3

A variety of massive volcanic and volcaniclastic rocks of felsic composition are included within Unit 3. These rocks are exposed in a discontinuous, folded, east-southeast trending belt that is succeeded

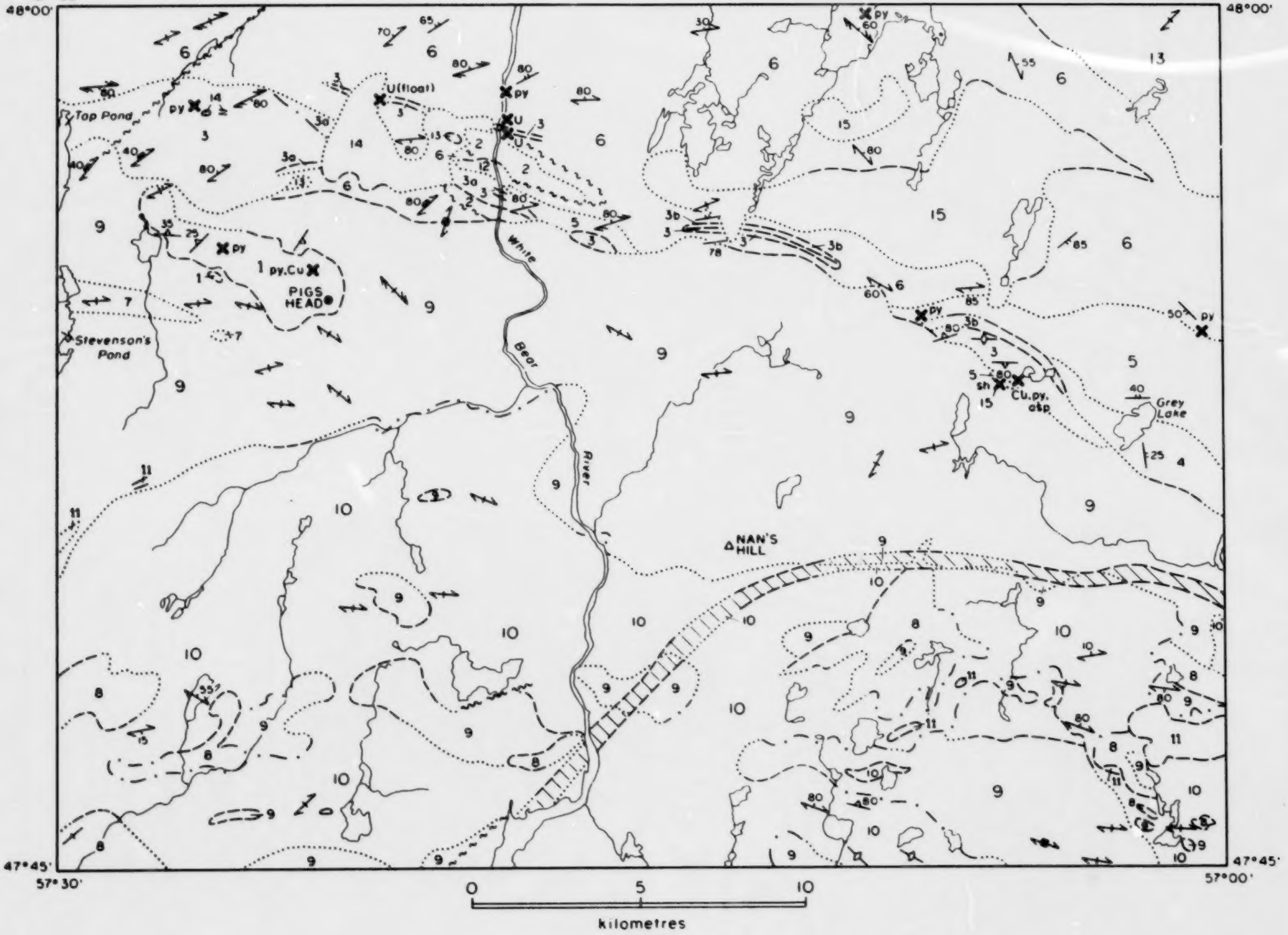
57° 30'
48°00'
57°00'
48°00'
47°45'
57° 30'
47°45'
57°00'
Top Pond
Stevenson's Pond
PIGS HEAD
U(float)
py
py.Cu
Cu.py. asp
sh
Grey Lake
NAN'S HILL
White
Bear
River
0
5
10
kilometres

Figure 1: *Geological map of the White Bear River (11P/14) area, Newfoundland.*

LEGEND

DEVONIAN(?) or earlier

15 Fine to medium grained, equigranular muscovite-biotite granite; lepidolite-tourmaline-garnet-bearing aplite; rare porphyritic granite.

14 Pink felsite and fine grained granite; muscovite-tourmaline leucogranite.

North Bay Granite (Unit 13)

13 Coarse grained feldspar porphyritic biotite granite.

12 Fine to medium grained, equigranular to porphyritic granite.

Burgeo Batholith (Units 9-11)

11 Fine to medium grained, pink equigranular biotite granite.

10 Medium grained, mainly equigranular biotite granite.

9 Variably (feldspar) porphyritic, medium to coarse grained, biotite (± rare hornblende) granite and minor adamellite.

ORDOVICIAN(?)

8 Psammite, semipelite, migmatite and associated granitoids.

La Poile Group

7 Gray sandstone.

Bay du Nord Group (Units 2 - 6)

6 Thickly to thinly bedded, gray psammite, semipelite, phyllite, sandstone, siltstone and shale.

5 Black slate, graphitic schist, phyllite and minor semipelite.

4 Medium to coarse grained sandstone and granule to pebble conglomerate; psammite.

3 Rhyolite flows, massive and banded felsic tuff. **3a**, siliceous bedded tuff; **3b**, tuffaceous sediments.

2 Mafic tuff and tuffaceous sediment; amphibolite.

ORDOVICIAN or earlier

1 Massive and layered metagabbro; metadiabase; minor pyroxenite and peridotite.

to the north by the clastic sedimentary facies of the Bay du Nord Group; in the south it is intruded by syn- to late tectonic porphyritic granite of the Burgeo batholith.

The diagnostic rock types of the unit are massive or banded, pink to buff rhyolite flows and ash-flow tuffs. While the flows are characteristically massive in nature, the ash-flow tuffs are either streaky or well banded. Many of the ash flows are rich in quartz crystals and flattened biotite-rich lapilli. Between Top Pond and White Bear River, the rhyolitic flows and ash flows are replaced northwards and eastwards by a laterally equivalent succession of intercalated biotite-rich ash flows, psammite and silicic bedded tuff (subunit 3a). The latter rock type is more extensive east of White Bear River, where it forms a mappable unit (subunit 3b) that overlies massive rhyolite. Coarser grained pyroclastic rocks are atypical of the Bay du Nord Group in this area, occurring in a small roof pendant in the northern part of the Burgeo batholith.

The relationship of Unit 3 to the mafic rocks of Unit 2 is unclear. Unit 3 is not in contact with the ophiolitic rocks of Unit 1, but less than 10 km to the west, in the adjacent Peter Snout map area (11P/13E), conglomerate beds within stratigraphic equivalents of Unit 3 are rich in gabbroic detritus (O'Brien, 1983). If one can assume that this detritus is derived from ophiolitic gabbro of Unit 1, then the existence of these gabbro-boulder conglomerates together with the discovery of ophiolitic rocks in the White Bear River area can be regarded as evidence for the existence of ophiolitic basement to the Bay du Nord Group.

Unit 4

Unit 4 is a succession of sandstone and quartz-rich granule and pebble conglomerate that locally overlies felsic volcanics of Unit 3 on the south limb of a large scale F_2 syncline. The unit pinches out rapidly along strike to the west but outcrops again to the east, where it is folded around the hinge of the same west-plunging structure (Blackwood, *this volume*). Unit 4 is intruded to the south by porphyritic granite of the Burgeo batholith. The diagnostic rock types of the unit are green, siliceous, planar-bedded fine to coarse grained sandstones. Clastic quartz is readily visible in the coarser sandstones, which are interbedded with green, well rounded quartz granule and quartz-pebble conglomerate.

Unit 5

Unit 5 consists mainly of dark blue-gray and black, fine grained clastic sedimentary rocks that overlie volcanic rocks of Unit 3 and locally sedimentary rocks of Unit 4. It is exposed in a southeasterly trending belt east of White Bear River and is in places truncated by porphyritic granite of the Burgeo batholith. The characteristic rock type of the unit is a fine grained, thinly laminated black slate. The slate is typically highly contorted by folding and in many places is pyritic. Associated with the slate are black graphitic schist and phyllite, and thinly bedded black and gray semipelite.

Unit 6

Unit 6 is the most extensive subdivision of the Bay du Nord Group in this area. It is exposed in an arcuate belt up to 10 km wide, bounded to the north and south by the North Bay Granite and the Burgeo batholith, respectively, and also intruded along its length by late tectonic granitoids. Intensive folding precludes a meaningful estimate of the unit's thickness.

The unit's dominant and most typical rock types are variably deformed gray and green sandstone, siltstone and shale, and their metamorphic equivalents, psammite, pelite and phyllite. In the thermal aureole of the Burgeo batholith, Unit 6 clastics were metamorphosed to coarse grained staurolite-garnet schist (see below).

The sediments are characteristically well bedded and occur in planar beds of variable thicknesses, seldom in excess of 15 cm (Plate 2). Cross-stratification is rare; it occurs only in the cross-laminated layers where partial Bouma sequences are preserved. The latter are rarely well preserved; where recognizable, they indicate that much of the unit represents relatively distal turbidite facies. Nevertheless, the tuffaceous nature of some of the sediments, coupled with the presence of intercalated tuff beds indicates that the sedimentation was penecontemporaneous with volcanism.

La Poile Group (Unit 7)

The name La Poile Group was first used by Cooper (1954) to denote those volcanic and sedimentary rocks in the La Poile - Cinq Cerf area, which were exposed between the Bay d'Est Fault and the Chetwynd Granite. The group was later redefined by Chorlton (1978), who extended it towards

Plate 2: *Bedded sandstones of the Bay du Nord Group (Unit 6).*

the northeast and divided it into a sequence of volcanic and sedimentary rocks (Georges Brook Formation) and a subvolcanic pluton (Roti Granite). The group was extended further northwestwards across the Peter Snout area (O'Brien, 1983), where it is separated from the adjacent Bay du Nord Group by the Bay d'Est fault. The group is continuous eastwards from there into the present map area, where it is truncated by the Burgeo batholith.

Unit 7 forms a narrow, 1 by 5 km band within the Burgeo batholith north and northeast of Stephensons Pond. A smaller pod of partly migmatized metasediment lies less than 1 km east of the main body. The unit consists of fine to medium grained, massive and cross-stratified gray sandstone and cordierite hornfels.

Unit 8

Unit 8 consists of variably migmatized metasedimentary rocks and associated granitoids that occur as large inclusions within the Burgeo batholith. The unit is intruded by all phases of the batholith, but is restricted to its southern part, where it is in many places associated with equigranular granite. The protolith of the metasediments and migmatite is interpreted to be the Bay du Nord Group.

The dominant rock types of the unit are recrystallized psammite, semipelite and pelite. The metasediments are mainly dark gray or dark greenish brown, and are either massive or banded on scales varying from tens of millimetres to tens of centimetres. They have a prominent penetrative schistosity. In places they contain sillimanite, and underwent varying degrees of migmatization. The volume of granitoid within the migmatite varies from a small proportion of quartz, pegmatite and granitoid sweats cutting recrystallized metasediment to 10 to 20 percent metasediment, locally with amphibolite, in a porphyritic or equigranular granitoid host (Plate 3). The granitoids developed a local crude gneissic foliation. Such granitoids are particularly well exposed in the southwestern corner of the map area, in and around Kings Harbour Brook.

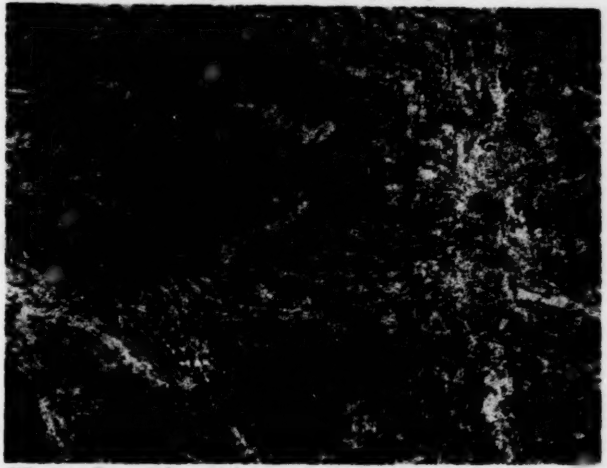

Plate 3: *Migmatite of Unit 8.*

BURGEO BATHOLITH (UNITS 9, 10 and 11)

The name Burgeo batholith is an informal name first used by Williams (1978). O'Brien (1983) retained the name in an informal way to denote the suite of granitoid rocks that intruded the La Poile Group in the southeastern part of the Peter Snout map area. The name is used here, in an informal fashion, to designate the granitoid rocks that lie to the south of, and intrude, the Bay du Nord Group in the White Bear map area. The batholith is tentatively subdivided into three distinctive intrusive phases which are interpreted to have a close genetic interrelationship. The batholith is presently interpreted to have intruded in several pulses throughout the main period of deformation.

Unit 9

Unit 9, the dominantly porphyritic phase of the Burgeo batholith, constitutes the northern part of the batholith and intrudes each of Units 1 to 8. The unit is also present in the south as separate massifs within the dominantly equigranular phase. The characteristic rock type of Unit 9 is medium to coarse grained porphyritic biotite granite. The granite is characterized by 1 to 1.5 cm microcline phenocrysts that locally constitute 60% of the rock. Biotite is ubiquitous and characteristically chloritized; it locally constitutes up to 15% of the granite. Amphibole is present locally. Plagioclase is extensively saussuritized. Slightly porphyritic granite and rare equigranular granite are intimately associated with the porphyritic phase locally. Where present, these phases are subordinate with respect to the porphyritic phase, and cannot be readily separated from it. In many areas, the unit contains a variety of cognate mafic, biotite-rich, and other amphibolitized xenoliths; these range in area from a few millimetres to several tens of centimetres. Near its contact with the Bay du Nord Group, the granite hosts numerous large migmatized metasedimentary xenoliths. The granite is variably deformed and in places contains two recognizable foliations; in many places the foliation is cataclastic (Plate 4). A strong cataclastic fabric is particularly well developed along the trace of the Dragon Bay Fault (Blackwood, 1983) (see below). The northern contact of Unit 9 with the Bay du Nord Group and ophiolitic rocks is sharp but locally irregular in detail. The contact with the La Poile Group to the south is more gradational.

Plate 4: *Foliated porphyritic biotite granite of the Burgeo batholith.*

Unit 10

Unit 10 consists mainly of equigranular biotite granite (Plate 5). The granite may be either massive or variably foliated and locally displays a pronounced igneous banding. It underlies much of the southern half of the map area, and in places has gradational contacts with adjacent porphyritic granite of Unit 9; locally, the two phases cannot be readily separated. Mineralogically, the granite is characterized by up to 40% K-feldspar, 10 to 20% oligoclase and locally up to 5% biotite. Rare muscovite was noted. Average grain size is variable between 1.0 and 3.0 mm. Subordinate amounts of adamellites are also included in this unit. In the southeastern quadrant of the area, the unit is characterized by variably developed light and dark, biotite-rich and biotite-poor bands which vary in width from several millimetres to several centimetres. The granite contains a variety of mafic to intermediate xenoliths.

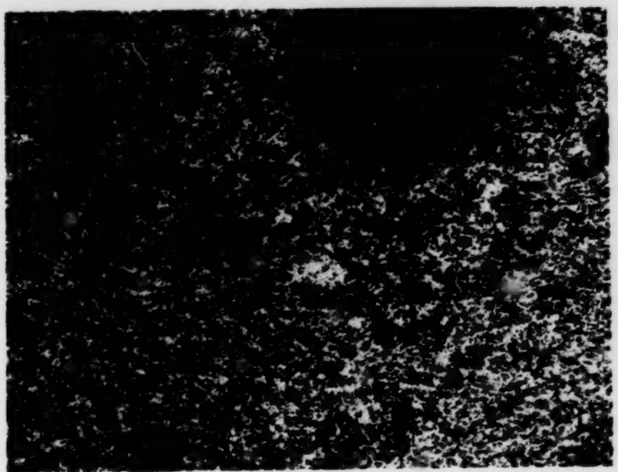
Plate 5: *Equigranular biotite granite of the Burgeo batholith.*

Unit 11

Unit 11 represents the latest intrusive activity of the Burgeo batholith in the map area. It forms several smaller plugs and dikes in the southeastern corner and the westernmost parts of the area, south of Stevenson's Pond. It intrudes both porphyritic and equigranular phases of the batholith and also the migmatites of Unit 8. The granite is only weakly foliated, and near Kings Harbour Brook, post-tectonic dikes of similar lithology intrude migmatite and deformed granite. The characteristic rock type of the unit is pale pink to red, fine grained, equigranular granite rich in K-feldspar with minor biotite. Locally the granite contains muscovite.

Unit 12

Unit 12 constitutes several small areas of deformed porphyritic granite that lie north of the Burgeo batholith in the vicinity of the White Bear River. The granites intruded various levels of the Bay du Nord Group syntectonically. It is likely that these granites are related to early Burgeo batholith plutonism. Unit 12 is not unlike the porphyritic phase of the Burgeo batholith, as it is characterized by strongly deformed, coarse to medium grained, K-feldspar porphyritic biotite granite. The grain size was significantly reduced in areas of high strain.

North Bay Granite (Unit 13)

The name North Bay Granite was introduced by Jewell (1939) in order to designate the granitoids in the North Bay and East Bay areas of the south coast. The name has been retained by later workers who extended the boundaries of the granite northwards and westwards (eg. Dickson and Tomlin, 1982; Blackwood, 1983). The granitic rocks in the northeastern corner of the map area are an extension of the main body of North Bay Granite to the east.

In the White Bear River area, the North Bay Granite is dominantly medium to coarse grained, locally megacrystic biotite granite. The coarser grained varieties are typified by euhedral K-feldspar phenocrysts up to 12 cm in length. The granite is characteristically massive but locally does develop northwest trending narrow (<1 cm) shear zones. The North Bay Granite was intruded into Unit 6 of the Bay du Nord Group after the first main period of deformation.

Unit 14

Unit 14 is a poorly exposed granite pluton that is intrusive into volcanic and sedimentary rocks of the Bay du Nord Group and earlier granites of Unit 13. At least three rock types are included within the pluton: pink felsite, pink microgranite or aplite, and fine grained leucogranite. The felsite is an essentially structureless aphyric rock, locally containing small inclusions of Bay du Nord Group metasediments. The microgranite in places has a strong foliation and may be gradational into the fine grained leucogranite phase. The latter is deformed, contains muscovite, tourmaline and rare biotite, and is locally quartz porphyritic. Most of the area designated as this unit in the map area is drift-covered, and may thus include earlier granitoids.

Unit 15

Unit 15, informally referred to by explorationists as the Cochrane Pond granite, is the youngest plutonic rock in the area. The granite is late tectonic and is intrusive into metasediments of the Bay du Nord Group in the northeast quadrant of the map area. The most characteristic rock type of the granite is a quartz-rich, leucocratic, fine to medium grained, equigranular, muscovite-biotite granitoid. The granitoid is either undeformed or locally weakly foliated, and in places is extensively sericitized and/or saussuritized. The granite is cut locally by tourmaline-bearing quartz-rich pegmatite dikes. Associated with the leucogranitoid phase are dikes of lepidolite-tourmaline-garnet-bearing aplite. Locally, the equigranular phase is associated with slightly porphyritic granitoid. Unit 15 bears lithologic similarities to granites of Unit 14 and it is likely that both plutons are genetically closely related.

Structure and Metamorphism

All rocks within the map area display the variable effects of a medium to high grade regional, post-Ordovician tectonothermal event. Deformations associated with this event produced two regional foliations, first and second generation folds, and major faults and related mylonite zones. The regional metamorphism, associated with the first and main deformational episode, appears to have occurred under mid-greenschist to upper amphibolite facies conditions.

The first regional tectonic fabric (S_1) is recognizable, albeit variably developed, in all but the youngest plutonic rocks within the area. In the gabbros and affiliated rocks of Unit 1, it is well developed, although not everywhere is it penetrative. Where penetrative, however, the fabric can be shown to be approximately parallel to crude metamorphic banding in the gabbro. S_1 is pervasive throughout all units of the Bay du Nord Group. The tuffaceous metavolcanic and metasediment exposures of Unit 2 are characterized by a strong, closely spaced penetrative foliation. Likewise, the finer grained felsic tuffaceous deposits of Unit 3 are characterized by a penetrative fabric, defined by biotite and/or muscovite. The aphyric rhyolite flows, because of their more resistant nature, rarely display macroscopic flattening. However, in the coarser grained porphyritic flows, tails are developed on the feldspar phenocrysts. The clastic sedimentary facies of the group, particularly Units 4 and 5, are characterized by an essentially ubiquitous fine, penetrative foliation that is usually coplanar to bedding and that, in rare exposures, can be shown to be axial planar to F_1 isoclinal folds. The intensity of the fabric within the clastic facies of the group is variable and appears to increase generally with proximity to the Burgeo batholith. In the northern parts of the area, the first fabric is developed axial planar to upward facing folds that are overturned to the south.

The granitoid rocks within the Burgeo batholith are variably affected by a regional foliation that is, in a regional sense, parallel to or concordant with the S_1 regional foliation in the Bay du Nord Group. Within the granitoids, this fabric varies markedly in intensity. This is at least in part due to the apparent synkinematic nature of the batholith. In several areas, penetratively deformed granitoid phases were intruded by less intensely deformed granitoids of the same phase. In the adjacent Dolland Brook area, the synkinematic nature of this granite can be clearly demonstrated (see Blackwood, *this volume)*; there, the granite both intrudes D_1 mylonite zones and is cataclastically deformed by the same D_1 structures.

In the northern contact zone of the Burgeo batholith, dikes of granite show variable relations with respect to the main foliation in Bay du Nord Group country rock. Typically, the granitoid contains a fabric parallel to that in the country rocks but less penetrative. In places the fabric, both in the granite dikes and the sediment, is overprinted by a S_2 crenulation cleavage. In the southeastern quadrant of the map area, coincident locally with the contact of Units 9 and 10, intense cataclastic fabrics are well developed within the batholith. Locally, the regional fabric can be traced into a mylonite zone with a narrow (<1 km) transition from foliated biotite granite, through protomylonite to ultramylonite; the latter is in places cut by pseudotachylite veins. This major D_1 mylonite zone may represent the westward extension of the Dragon Bay fault (Blackwood, 1983). The mylonite zone trends east-west for a distance of some 15 km, there trends west-southwest and southwest and continues towards the southern part of the area, where it may be sited along White Bear Bay. Another zone of extensive cataclastic deformation is developed in Unit 9 of the batholith immediately east of Top Pond. There, poor exposure precludes delineation of the mylonite zone to the northeast and much of the area along strike of the zone is underlain by Bay du Nord Group clastic rocks, in which cataclastic fabrics would unlikely be developed. This mylonite may form the northeastern extension of the Bay d'Est fault (Cooper, 1954; Chorlton, 1980; O'Brien, 1983). Narrower, less extensive northeast trending mylonites are exposed in the northern parts of the batholith between Top Pond and White Bear Bay.

The second foliation is also developed in the North Bay Granite. The fabric there is generally not as intense as that developed in the Burgeo batholith; nevertheless, narrow (<1 cm) northwest trending cataclastic zones, possibly related to syn-F_2 faulting, were noted in the northeasternmost part of the area.

The second deformation produced a regionally developed fabric (S_2) that varies from a weak crenulation through strain-slip cleavage to a strong composite foliation with transposition of the earlier fabric (S_1) (Plate 6). The strong second regional foliation is most readily identifiable, and presumably preferentially developed in the clastic facies of the Bay du Nord Group where it is axial planar to small scale, upright F_2 folds. Nevertheless, a second coarse strain-slip cleavage locally overprints the earlier fabric in Units 1, 2 and 3 and also in Unit 9 of the Burgeo batholith. Large scale F_2 structures are not definable in the map area. A large scale F_2 syncline, outlined by a felsic volcanic band in Bay du Nord Group, has been mapped in the adjacent Dolland Brook area (Blackwood, *this volume)*. Presumably, Units 3, 4 and 5 in the easternmost part of the White Bear River area lie on the southern limb of this structure.

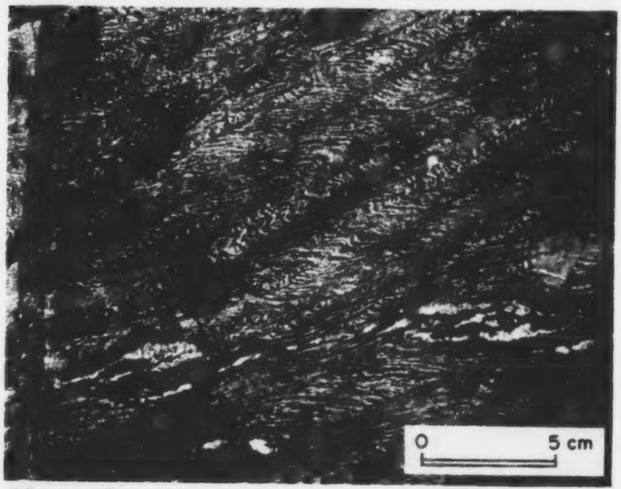

Plate 6: *Transposition of S_1 in Bay du Nord Group metasediment.*

In the southwest corner of the area, dikes of Unit 11 are intrusive into deformed porphyritic granite (Unit 9), truncating the first fabric in the granite. The dikes themselves locally have a weak fracture cleavage developed. Similar rocks in the southeastern quadrant of the area constitute the least deformed phase of the Burgeo batholith. Units 14 and 15 are the least deformed and also the youngest granitoids in the area, the latter containing only a single, weak, locally developed S_2 fabric.

Regional metamorphism accompanied the first main episode of deformation. Within the Bay du Nord Group it varies in grade from mid- to upper greenschist facies in the northern parts of the Bay du Nord belt to upper amphibolite facies adjacent to and within the Burgeo batholith. A progressive increase in grade from sandstone and phyllite in the north to porphyroblastic garnet-muscovite-biotite schist in the south is evident. Highest grade rocks are the migmatites (Unit 8) within the Burgeo batholith; it is probable that these rocks represent the higher grade metamorphic equivalents of the Bay du Nord Group to the north.

Mineralization and Exploration Potential

Mineralization of varying significance is found within Units 1, 3, 5, 6, 14 and 15. Mineralization within the ophiolitic rocks and overlying Bay du Nord Group includes pyrite, chalcopyrite and arsenopyrite; granitoid-related mineralization includes scheelite, molybdenite and uranium.

The layered and massive gabbros of Unit 1 are host to at least two minor base metal occurrences. Both are areally insignificant and consist mainly of pyrite occurring along fractures within the gabbro. A small showing north of Pigs Head contains minor malachite; arsenopyrite was reported from the same area (Scott and Conn, 1950).

Volcanic rocks of the Bay du Nord Group are host to a significant sulfide occurrence near Grey Lake, in the west-central part of the map area. There, altered massive rhyolite of Unit 3 contains disseminated chalcopyrite, pyrite and arsenopyrite. Rhyolite tuff approximately 500 m north of the above occurrence also contains traces of pyrite. These showings are significant in that they occur at the same stratigraphic level as the Strickland massive sulfide deposit to the southwest (Swinden, 1981), namely, within the uppermost part of the Bay du Nord volcanic succession, immediately below graphitic pelites and slates. Unit 3 also contains very minor pyrite occurrences along strike in White Bear River and northeast of Top Pond.

The Bay du Nord Group sedimentary rocks, especially the slates and pelitic schists of Unit 5, contain minor pyrite occurrences. Small pyrite occurrences have also been found in Unit 6 in the northern parts of the area. Pyrite, in association with scheelite and arsenopyrite, has been reported in quartz veins in sediments from the northern parts of the area (Scott and Conn, 1950; *see* Smyth, 1979).

The most significant mineralization in the map area is associated with the late tectonic granitoids that intrude the Bay du Nord volcano-sedimentary belt, namely Units 14 and 15. These units contain muscovite-biotite leucogranitoids and muscovite-tourmaline-garnet-bearing aplitic phases, and are anomalously radioactive with variable backgrounds of 200 to 400 c.p.s. (total counts, BGS-1 SCINTREX scintillometer).

Unit 15 has long been known to host significant scheelite showings and float in the vicinity of Cochrane Pond (Scott and Conn, 1950; Smyth, 1979). Other smaller fracture coatings of scheelite have been found in a dike or small plug of similar granitoid almost 2 km south of the main pluton about 3 km northwest of Grey Lake (Figure 1).

Three new uranium showings were discovered during the course of this mapping program. The showings occur in Bay du Nord Group volcanic and sedimentary rocks; two of the showings are areally associated with muscovite-garnet leucocratic aplite dikes and quartz veins presumably related to either Unit 14 or 15. One showing consists of several large (≤ 10 to 20 kg) tabular radioactive boulders interpreted to be suboutcrop of Unit 3 biotite-rich metatuff. These boulders yield readings in excess of 10,000 c.p.s. (total counts, BGS-1) and have yellow uranophane staining; background radioactivity in rocks of similar lithology along strike to the west gives about 150 c.p.s. (total counts, BGS-1). Two other showings, several tens of metres distant from each other, occur in metavolcanic and metasedimentary rocks respectively. These showings lie approximately 3 km along strike to the east of the above radioactive suboutcrop. The sediment-hosted mineralization consists of radioactive, quartz-veined, staurolite porphyroblastic semi-pelitic schist (Unit 6) containing tuffaceous volcanic interbeds; total counts of 6,000 c.p.s. (BGS-1) were recorded at this showing. A third radioactive zone of approximately 2000 c.p.s (BGS-1) occurs within a felsic tuff layer of the metasediments.

In summary, the greatest potential for discovery of economic mineralization lies in the granitoid rocks of Units 13, 14 and 15. All should be treated as having high potential Sn-W-U mineralization. The earlier plutonic rocks of the Burgeo batholith also have anomalously radioactive areas of 3 to 4 times background and should not be overlooked in assessing the exploration potential of the area. The greatest potential for base metal mineralization lies within the upper levels of the volcanic part of the Bay du Nord Group.

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S.J. O'Brien

S. Tomlin

Geology of the Wolf Mountain (east half) and Dolland Brook (east half) map areas, south-central Newfoundland

by

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Abstract

The Wolf Mountain (east half) and Dolland Brook (east half) map area, in south-central Newfoundland, contains metasedimentary and minor volcanic rocks assigned in part to the Lower to Middle Ordovician Spruce Brook Formation(?), Baie d'Espoir Group and Bay du Nord Group. These rocks have been deformed and metamorphosed in the greenschist facies, with migmatization of the northern part of the Spruce Brook Formation and all of the Bay du Nord Group. A small area around Dolland Pond contains metasediments of possible Silurian age. The Ordovician units have been intruded by the Silurian-Devonian North Bay Granite, a large batholith composed primarily of massive to very weakly foliated, biotite ± muscovite, K-feldspar porphyritic granite. Some of the smaller, earlier granitoid units of the North Bay Granite possess a strong foliation. The Burgeo Batholith, within the map area, is strongly mylonitized and forms part of a 100 km long mylonite zone.

A one kilometre wide, curved belt of strongly foliated muscovite ± garnet ± biotite granite and pegmatite extends across the north part of the area (from Meelpaeg Lake to Dolland Pond) and continues to the east into the D'Espoir Lake map area. The belt of granitoids may represent a cataclastic zone formed by southwesterly directed overthrusting of the Ordovician metasediments and the granitoids which intruded them across the main mass of the North Bay Granite.

The youngest igneous rock unit consists of a number of north trending large quartz-feldspar porphyry dikes which have intruded the North Bay Granite in the southern part of the map area.

Minor scheelite mineralization was discovered in the North Bay Granite and this corresponds with an area of anomalous tungsten in lake sediments. Several large quartz veins, associated with faults, occur within the North Bay Granite but contain no apparent mineralization.

Introduction

Regional Setting

The North Bay Granite in south-central Newfoundland is a large (>3000 km^2) composite pluton which intruded Lower to Middle Ordovician sedimentary rocks during the later stages of the Silurian-Devonian Acadian Orogeny. The batholith is curved in outline and lies in the central part of the Hermitage Flexure, a major structure defined by pronounced swings in the generally northeasterly Appalachian trend of the Lower Paleozoic rocks in eastern and southern Newfoundland (Williams et al., 1970).

The North Bay Granite is economically significant as it is the host of W-Mo mineralization at its northern termination 10 km northwest of Meelpaeg Lake. With mapping carried out by Blackwood (1984), and O'Brien and Tomlin (1984), this work completes mapping and geochemical sampling of the North Bay Granite in south-central Newfoundland (Blackwood, 1983; Colman-Sadd, 1976, 1983; Colman-Sadd et al., 1981; Dickson, 1982; Dickson and Tomlin, 1983). Possible continuations of the North Bay granitoid terrain in central Newfoundland will be examined during 1984 and 1985.

Location and Access

The Dolland Pond (11P/15E) and Wolf Mountain (12A/2E) map area is located in south-central Newfoundland. The closest, easily accessible settlement is the town of

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St. Alban's, located 50 km east of the Dolland Brook map area. Access is gained to Meelpaeg Lake in the Wolf Mountain map area by woods roads and Newfoundland Hydro access roads from Millertown, 80 km to the north. Helicopter support is available from St. Alban's and nearby Milltown.

The area was mapped at a scale of 1:50,000 mainly from helicopter-placed fly camps and by boat around Meelpaeg Lake. The poorly exposed area between 47°50'N and 47°55'N was surveyed by helicopter.

Previous Work

The earliest work in the map area was carried out by the Buchans Mining Company with a survey carried out to the southeast of Meelpaeg Lake (Phendler, 1950) and to the southwest of Dolland Brook (Scott and Conn, 1950; see also Smyth, 1979). The only other major work in the area was by Williams (1970, 1971) who carried out 1:250,000 mapping and outlined the major units.

Lake sediment geochemical surveys in this area indicated that the granitoid rocks were relatively low in anomalous concentrations of Cu, Ag, Mo, U and F (Butler and Davenport, 1978; Davenport and Butler, 1981). However, tungsten values were anomalous over several parts of the North Bay Granite within the Dolland Brook map area (Davenport and Butler, 1982) and an area of the North Bay Granite with known tungsten mineralization, 10 km northeast of Meelpaeg Lake (Dickson, 1982). A stream sediment and soil survey carried out over the tungsten anomalies (McConnell, 1984) resulted in the discovery of minor scheelite-pyrite mineralization in granite bedrock east of Dolland Brook (Figure 1).

Adjacent map areas to the west, 11P/15W and 12A/2W, have been surveyed at a scale of 1:50,000 by Blackwood (1984) and Dickson (1982), respectively. The map areas to the east, 12A/1 and 11P/16, have also been mapped at 1:50,000 by Colman-Sadd (1984) and Dickson and Tomlin (1983), respectively.

General Geology

The Dolland Pond (11P/15E) and the western half of Wolf Mountain (12A/2E) map areas are dominated by a variety of granitoid rocks which form the southwestern part of the late Acadian North Bay Granite (Jewell, 1939) which underlies an area in excess of 3000 km^2. To the northeast, in the Wolf Lake - Meelpaeg Lake area, the geology is more complex with much of the ground underlain by a variety of metasediments provisionally assigned to the Lower to Middle Ordovician Spruce Brook Formation (Colman-Sadd and Swinden, 1982) and the Baie d'Espoir Group (Jewell, 1939; Colman-Sadd, 1976). To the southwest of Dolland Brook, the North Bay Granite is separated from the highly mylonitized granite of the late Acadian Burgeo Batholith by a narrow belt of migmatite and granite veins assigned to the Lower to Middle Ordovician Bay du Nord Group (Chorlton, 1978).

An elongate belt of highly deformed leucocratic granitoids separates the Ordovician metasediments and smaller granitoid intrusions, mainly within the Wolf Mountain map area, from the main mass of the North Bay Granite to the south. A similar zone of highly deformed granitoids with associated migmatite separates the Ordovician Salmon River Dam Formation in the north from the main mass of the North Bay Granite in the adjacent D'Espoir Lake map area to the east (Dickson and Tomlin, 1983).

In the southern part of the Dolland Brook map area, four quartz-feldspar porphyry dikes intrude the North Bay Granite and represent the last phase of acid magmatism in the area.

The map area is covered with a thick blanket of till in the vicinity of Meelpaeg Lake, Wolf Lake, Dolland Pond and the Dolland Brook area. Glacial striae and stoss and lee surfaces indicate a south-southeasterly direction of ice flow. Eskers are common with an 8 km long esker preserved in the northern half of Wolf Lake.

Description of Units

Lower to Middle Ordovician Spruce Brook Formation(?) (Unit 1)

The term Spruce Brook unit was informally introduced by Colman-Sadd and Swinden (1982) for a sequence of Lower to Middle Ordovician quartz-rich turbiditic sandstone and minor conglomerate and shale which had been overthrust by ophiolitic rocks in the Miguels Lake - Pipestone Pond area, 60 km northeast of Meelpaeg Lake. The name has since been changed to Spruce Brook Formation (Colman-Sadd, personal communication, 1983). Subsequent mapping by Colman-Sadd (1983, 1984) has tentatively extended the Spruce Brook Formation to the southwest, outside of the ophiolitic complex, and the unit continues into the Wolf Mountain map area.

Within the Wolf Mountain map area, the Spruce Brook Formation has been divided into four subunits, based on lithology and grade of metamorphism. Subunit 1a is dominantly a biotite ± muscovite psammitic schist with minor interbedded semipelite.

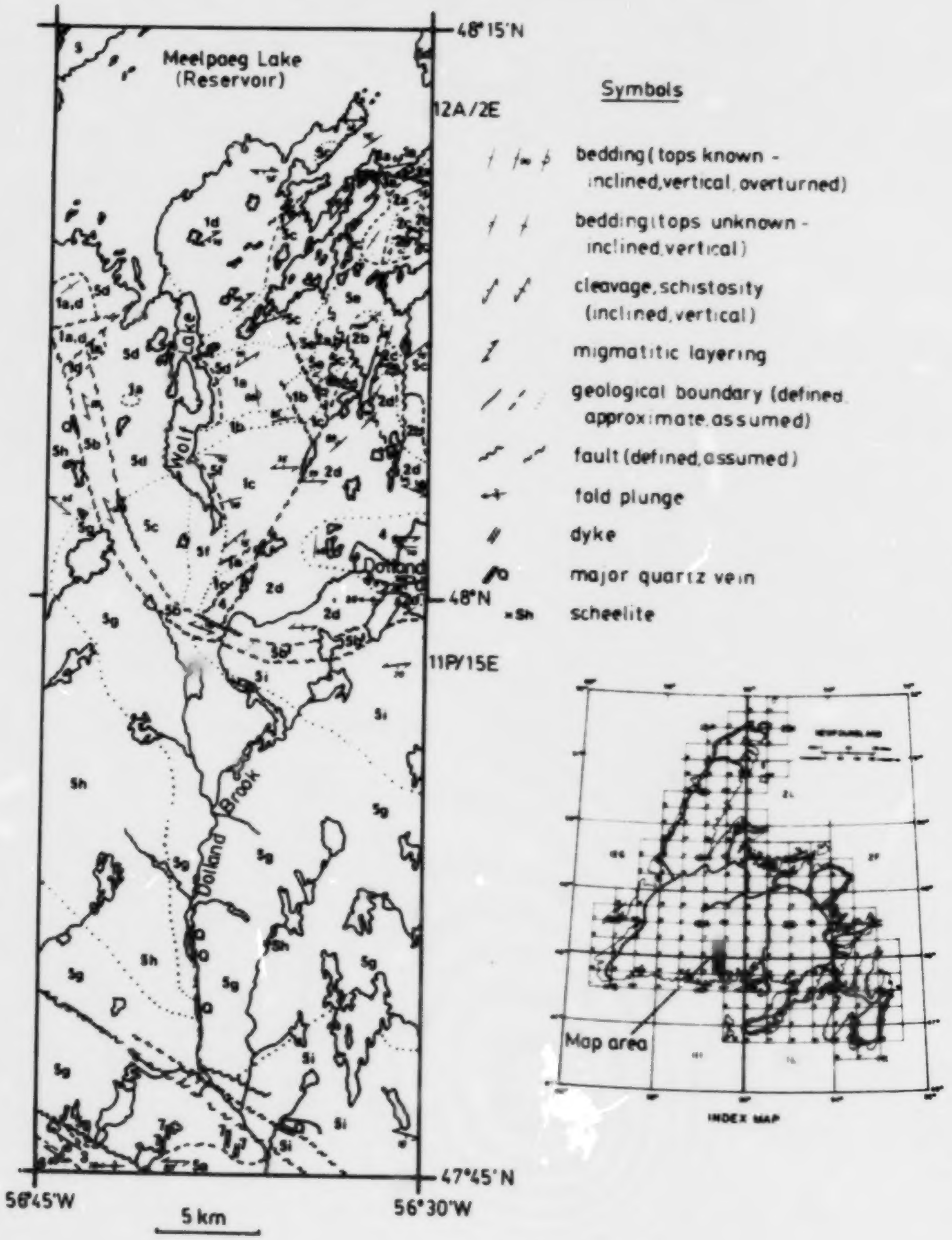
48°15'N
Meelpaeg Lake
(Reservoir)
12A/2E
Wolf Lake
Dolland
48°N
11P/15E
Dolland Brook
47°45'N
56°45'W
56°30'W
5 km
Symbols
bedding (tops known - inclined, vertical, overturned)
bedding (tops unknown - inclined, vertical)
cleavage, schistosity (inclined, vertical)
migmatitic layering
geological boundary (defined, approximate, assumed)
fault (defined, assumed)
fold plunge
dyke
major quartz vein
scheelite
Sh
Map area
INDEX MAP

Figure 1. Geological map of the Wolf Mountain (12A/2E) and Dolland Brook (11P/15E) map areas.

LEGEND

DEVONIAN OR YOUNGER

7 Pink, massive, very fine grained to fine grained, quartz-feldspar porphyritic dikes.

SILURIAN TO DEVONIAN

Burgeo Batholith

6 Pink, protomylonitic to mylonitic, very fine grained to medium grained, locally K-feldspar porphyroclastic, biotite granite.

North Bay Granite (subunits 5a-5b)

5a Pink to buff, foliated, medium grained, equigranular to porphyritic, biotite ± muscovite granodiorite and granite.

5b Pink to white, strongly foliated, medium to coarse grained, equigranular to pegmatitic, muscovite-garnet and muscovite-biotite granite; **5b'** contains numerous xenoliths of migmatite, psammite, and foliated tonalite.

5c Buff to gray, foliated, medium to coarse-medium grained, equigranular, biotite granodiorite and minor tonalite; locally intruded by garnet-muscovite aplite and pegmatite veins.

5d Buff, massive, medium grained, equigranular, biotite granodiorite and granite; granite becomes fine grained and muscovite-bearing southwest of Meelpaeg Lake.

5e Buff, massive, medium grained, equigranular, biotite granite; includes minor biotite-muscovite granite.

5f White to buff, massive, coarse grained, equigranular, biotite-muscovite granite.

5g Pink to buff, massive to weakly cleaved, medium to coarse-medium grained, K-feldspar porphyritic, biotite granite; screens of foliated granite and migmatite common southwest of Dolland Brook.

5h Pink to buff, massive to weakly cleaved, medium to coarse-medium grained, K-feldspar porphyritic, biotite ± muscovite granite.

5i Pink to buff, massive to weakly cleaved, medium grained, K-feldspar porphyritic, biotite-muscovite granite.

SILURIAN?

4 Interbedded sandstone, siltstone and pebble conglomerate; minor subangular cobble conglomerate.

LOWER TO MIDDLE ORDOVICIAN

Bay du Nord Group

3 Highly deformed migmatitic metasediments cut by numerous granitoid veins, dikes and small granitoid plugs.

Baie d'Espoir Group (subunits 2a-2d)

2d Gray and green, thinly bedded, cleaved pelite and semipelite.

2c Very thickly bedded, brown weathering, gray massive sandstone, minor interbeds of subunit 2b.

2b Thinly bedded, highly folded black graphitic pelite and semipelite.

2a Thickly bedded, schistose quartz-crystal tuff and coarse tuffaceous sandstone.

Spruce Brook Formation (subunits 1a-1d)

1d Migmatite, psammite, and numerous granitoid dikes: high grade equivalent of 1a, 1b.

1c Orthoquartzite cobble clast-supported metaconglomerate, with minor slate and quartzite matrix-supported breccia and coarse metasandstone.

1b Thinly bedded pelite and minor psammite and semipelite.

1a Dominantly biotite psammite and orthoquartzite with minor semipelite.

Bedding is rarely preserved. Locally the unit consists of 15 to 30 cm thick beds of quartz-rich sandstone with minor cross-laminations. Subunit 1b is dominantly a pelitic sequence with minor interbedded psammite, and probably overlies subunit 1a. Subunit 1c is a coarse clastic unit which comprises orthoquartzite - cobble conglomerate, coarse pelitic-clast breccia and minor interbedded granule conglomerate, coarse sandstone and semipelite. The clast lithologies can be matched to those of underlying subunits 1a and 1b.

Subunit 1d is considered to be the high grade equivalent of subunit 1a, and is dominated by migmatite and biotite psammite which are intruded by abundant granitic veins and pegmatite. Two small basic dikes, now converted to amphibolite schist, intrude the Spruce Brook Formation west of Wolf Lake.

Lower to Middle Ordovician Baie d'Espoir Group (Unit 2)

The Baie d'Espoir Group (Jewell, 1939; Colman-Sadd, 1976) lies to the southeast of the Spruce Brook Formation and is separated from it by assumed faults throughout much of the map area. Only in the area east of Meelpaeg Lake is there no apparent evidence for a fault contact between the two units.

The Baie d'Espoir Group is divided into four subunits based on rock type. Subunit 2a consists of thickly bedded, schistose quartz-crystal tuff and coarse tuffaceous sandstone. The subunit may overlie the Spruce Brook Formation in the area southeast of Meelpaeg Lake but the contact is not exposed. A significant geological break is present, however, as the Spruce Brook Formation in the area consists of thinly bedded pelitic, semipelitic and psammitic biotite-muscovite-andalusite schist which is distinct from the tuff. Subunit 2b consists of thinly bedded, graphitic-pyritic, black semipelite and pelite which is interbedded with subunits 2a and 2c in the area southeast of Meelpaeg Lake. About 10 to 15 km east of Wolf Lake, subunit 2b is extensively developed without the other subunits. Subunit 2c consists of very thickly bedded, virtually featureless, brown weathering, gray metasandstone with minor interbeds of pelite similar to subunit 2b. Subunit 2d consists of the gray to green pelitic and semipelitic units which are poorly exposed in a zone around Dolland Pond. About 5 to 8 km north-northwest of Dolland Pond, the unit is reasonably well exposed and consists of brown weathering, 5 to 10 cm thick, parallel bedded, massive green pelite and semipelite with a poorly developed cleavage. Southwest and west of Dolland Pond, pelite and interbedded pelite and semipelite are exposed. These rocks are tentatively correlated with subunit 2d to the north.

Lower to Middle Ordovician Bay du Nord Group (Unit 3)

Unit 3 is exposed in the southwest corner of the map area and consists of a narrow belt of migmatite and foliated granitoid dikes. The migmatites are interpreted to be part of the Lower to Middle Ordovician Bay du Nord Group which is more extensively developed immediately to the west (Blackwood, 1984). The migmatites consist of biotite ± muscovite psammite with a granitic melt fraction, both of which have been intruded by numerous mainly muscovite-biotite granite and pegmatite veins. Locally, small plugs (<200 m diameter) of foliated, leucocratic, muscovite-garnet granite intrude the migmatite. The unit was post-tectonically intruded by the North Bay Granite.

Silurian(?) Sandstone, Siltstone and Conglomerate (Unit 4)

Unit 4 consists of a weakly metamorphosed, deformed and cleaved, medium bedded (30 cm) sandstone, pebble conglomerate and siltstone which is exposed mainly around Dolland Pond (see also Colman-Sadd, 1984). Three kilometres west of Dolland Pond, the unit consists of a thickly bedded, poorly sorted, matrix-supported, angular, subangular to subrounded cobble to pebble conglomerate. Clasts are mainly of sedimentary origin with chert and shale fragments being the most abundant. The matrix consists of poorly sorted rock and crystal fragments cemented by pelite. The sandstone and siltstone beds locally display crossbedding and graded bedding, but more commonly only parallel laminations are present. Williams (1970) noted that this unit is similar to the Silurian Goldson Formation in Notre Dame Bay, and Colman-Sadd (1984) notes a similarity to the Silurian Botwood Group exposed to the northeast in the West Gander Rivers area (see Blackwood, 1981; Colman-Sadd, 1982).

Silurian-Devonian North Bay Granite (Unit 5)

The North Bay Granite within the map area has been divided into nine subunits based on mineralogy and degree of deformation. The essential features of each subunit are listed in the legend to Figure 1. The numerous smaller intrusions east of Wolf Lake are tentatively included in the North Bay Granite.

The main mass of the North Bay Granite (subunits 5g, 5h, 5i), in the Dolland Brook area, is dominated by very similar granites which vary only in the presence or absence of muscovite. Xenoliths of migmatite and foliated granite are common in subunit 5g within 5 km of the contact with Unit 3. A large xenolith of amphibolite schist was found at one locality and is probably derived from the Bay du Nord Group (see Blackwood, 1984).

Subunit 5a is considered to predate subunits 5g and 5i as it usually contains a strong penetrative fabric generally absent in subunits 5g and 5i.

Subunits 5h and 5h' form a major zone of highly deformed leucocratic granitoids. There is generally an abrupt change in rock type and degree of deformation between subunits 5h and 5h' and the juxtaposed granitoid subunits 5c, 5d, 5f, 5g and 5i and subunit 2d. The contacts are interpreted to be faults and the effects of the faulting are exposed on Dolland Pond, Dolland Brook, southwest of Wolf Lake and west of Wolf Lake where the granite has been injected by abundant quartz veins. In the other areas, the granite is brecciated and strongly sheared.

Subunit 5h' is distinguished from subunit 5h by the presence of abundant xenoliths of foliated diorite and tonalite, migmatite and psammitic schist in subunit 5h', of which the latter two may have been derived from the Spruce Brook Formation. The adjacent Baie d'Espoir Group, to the north, consists mainly of low grade slate and is clearly not the source of the migmatite.

Silurian-Devonian Burgeo Batholith (Unit 6).

A small portion of the Burgeo Batholith, which is an extensively developed granitoid unit located to the southwest of the Dolland Brook map area (Chorlton, 1980a,b; O'Brien, 1983; Blackwood, 1984; O'Brien and Tomlin, 1984), occurs in the southwest corner of the map area. The granite is a strongly mylonitized body which forms the northeast margin of the Burgeo Batholith and forms only a small part of a mylonite zone which extends from Dragon Bay 40 km to the southeast (Blackwood, 1983) into the adjacent Dolland Brook map area (11P/15W) (Blackwood, 1984), and beyond into the White Bear River (11P/14) (O'Brien and Tomlin, 1984), Ramea (11P/11) and Burgeo (11P/12) map areas where the mylonite zone bisects the Burgeo Batholith. The total length of this mylonite zone, which is about 1 km in width, is more than 100 km. Blackwood (1984) has shown that the mylonite zone bifurcates into zones of non-mylonitic to protomylonitic granitoids and ultramylonitic granitoids. These subdivisions of the mylonitic zone can be traced into the Dolland Brook (east half) map area (Figure 2) where the ultra

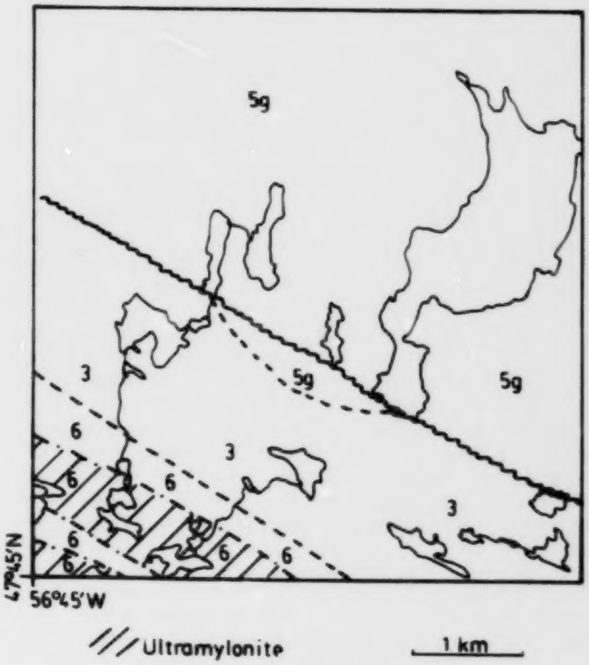

Figure 2: *Detailed map of the bifurcation of the mylonite zone in the southwestern corner of the Dolland Brook (east half) map area.*

mylonite portions of the mylonite zone are separated by a zone of protomylonitic granite.

The protolith of the mylonitic granitoids may be determined from the less deformed areas of the mylonite zone where the rock is a pink, slightly porphyritic, medium grained, biotite granite that is free from xenoliths of migmatite or foliated granitoids.

Devonian or Younger Quartz-Feldspar Porphyry Dikes (Unit 7)

Unit 7 consists of four quartz-feldspar porphyry dikes which intrude subunit 5g and may extend south to intrude subunit 5a (Scott and Conn, 1950). The dikes are straight, parallel sided, up to 15 m in width and more than 200 m long. They contain conspicuous 2 to 3 mm wide terminated quartz crystals and euhedral to anhedral feldspar in a fine grained, pink matrix. Two of the dikes contain a selvage of gray, very fine grained quartz-feldspar porphyry, up to 1 m wide, along their eastern margin. This may be a separate intrusion, as a similar zone was not observed on the western margin of the dikes.

Similar quartz-feldspar porphyry dikes are intrusive into the Burgeo Batholith (O'Brien and Tomlin, 1984) and the feldspar in these dikes is sanidine.

Structure and Metamorphism

The Spruce Brook Formation (Unit 1) and Bay d'Espoir Group metavolcanics and metasediments (Unit 2) are strongly deformed with a generally northeast trending cleavage or schistosity. This fabric is generally the only fabric present, but locally there is a transposed earlier fabric. Subunit 2b is characteristically highly folded with isoclinal folds plunging to the southwest at around 70°. Overturned folds were found in a few places. The migmatitic Spruce Brook Formation (subunit 1d) commonly contains at least two planar fabrics, the second commonly parallel to the migmatitic layering. The migmatites of the Bay du Nord Group (Unit 3) contain tight F_1 folds, which plunge to the west, and an associated axial planar cleavage. This cleavage is commonly transposed by a northwest trending schistosity considered to be S_2.

Unit 4 contains a weak cleavage which is generally parallel to bedding. At Dolland Pond where younging directions are known, an easterly plunging syncline can be defined (see also Williams, 1970).

The grade of metamorphism of the Spruce Brook Formation increases northward from lower greenschist facies, south of Wolf Lake, to upper amphibolite and migmatite grade toward Meelpaeg Lake. Andalusite is locally abundant in the amphibolite facies metasediments. The migmatite locally contains conspicuous pre-S_2 cordierite porphyroblasts. East of Wolf Lake, subunit 1a contains andalusite and cordierite porphyroblasts which are post-tectonic and are probably related to contact metamorphism from subunit 5d of the North Bay Granite.

The Baie d'Espoir Group lies generally within the greenschist facies. Close to contacts with the granitoid units, the rock is converted to a hard hornfels with skeletal andalusite in the pelitic units of subunit 2b.

Unit 4 lies within the lower greenschist facies which is similar to the surrounding pelites of the Baie d'Espoir Group.

The granitoid rocks (subunit 5c), southeast of Meelpaeg Lake, contain a moderately to strongly developed cleavage which is parallel to the main fabric in the metasediments. The fabric is defined by aligned biotite and flattened quartz and feldspar. There is no evidence of recrystallization.

Subunit 5b is deformed throughout its length with a strong fabric parallel to the strike of the subunit, and a relatively constant dip of between 50° and 70° to the northeast. This subunit may represent a major zone of dislocation as it lies along strike from a 1 km wide, 8 km long mylonite zone, well exposed to the northwest between Meelpaeg Lake dam and Granite Lake ditch to the north (Dickson, 1982). The zone of strongly deformed granitoids may be a continuation of the zone of strongly deformed granitoids which form the northern margin of the North Bay Granite in the adjacent D'Espoir Lake map area (Dickson and Tomlin, 1983). In this area, the Ordovician Salmon River Dam Formation is juxtaposed against the granite, and the contact varies from a probable faulted intrusive contact to a possible thrust contact where highly sheared magnesite and limestone slivers are present along a shear zone between D'Espoir Lake and Salmon River (Dickson and Tomlin, 1983). It is, therefore, possible that the granitoids and metasediments between Granite Lake ditch and Salmon River which lie to the north of the zone of highly deformed granitoids are in thrust contact with the North Bay Granite.

Mineralization

Lake sediment geochemical anomaly patterns indicate that the Dolland Brook area shows a potential for W mineralization (Davenport and Butler, 1982). Follow-up work by McConnell (1984), working east of Dolland Brook, has resulted in the discovery of minor scheelite-pyrite mineralization in brecciated, K-feldspar porphyritic, biotite granite.

Several major quartz veins occur along faults which cut subunits 5g, 5h and 5i of the North Bay Granite. Along Dolland Brook a prominent north trending fault scarp contains three large quartz veins. These veins are 10 to 15 m wide and more than 200 m long. They contain several generations of quartz which range from vuggy to massive milky quartz. The veins also contain inclusions of highly altered granite. East of Dolland Brook and southeast of the other quartz veins, another major quartz vein was discovered. This vein also lies along a fault and is similar in all respects to the other quartz veins. The veins will be analyzed for their gold content.

West of Wolf Lake, a large number of thin (5 to 10 cm) parallel quartz veins are injected into highly sheared granite of subunit 5h. During field work, another large quartz vein, similar to those at Dolland Brook, was discovered just to the west of the Wolf Mountain (east half) map area, about 2 km southeast of Meelpaeg Lake dam. These two occurrences both lie along the fault which extends toward the ditch at Granite Lake and contains two large quartz veins (Dickson, 1982).

Examination of all samples from these veins under ultraviolet light did not reveal the presence of fluorescent minerals such as scheelite or fluorite.

Geochemistry

Geochemical samples of granitoid rocks and quartz veins were collected using a 2 km by 2 km grid sampling system. Paucity of outcrop over much of the area prevented use of a random sampling technique. Granite samples were collected from 150 sites, and seven samples are from quartz veins. All samples will be analyzed for major and trace elements including W, U, Sn, Mo, Li and F. Samples collected in 1982 have been analyzed for major and trace elements including Li, F and Mo but not as yet for W, Sn and U. No anomalous values are readily apparent from the raw data.

Summary

The area of Wolf Mountain (east half) and Dolland Brook (east half) contains Lower Ordovician to Silurian(?) metasedimentary rocks intruded by a variety of granitoids which form part of the much more extensive Silurian-Devonian North Bay Granite.

The dominantly metasedimentary Units 1, 2 and 3 are assigned to the Lower to Middle Ordovician Spruce Brook Formation, Baie d'Espoir Group and Bay du Nord Group, respectively. The Spruce Brook Formation consists of psammite, pelite and a coarse cobble conglomerate. The formation is metamorphosed in the greenschist to upper amphibolite facies, and the northern portion of the formation has been converted to migmatite. The Baie d'Espoir Group is mainly in fault contact with the Spruce Brook Formation and is composed of a lower tuff unit overlain by a thick sequence of interbedded pelitic, semipelitic and psammitic units. The pelitic units are strongly deformed with tight isoclinal folds. The other units are less obviously deformed. Metamorphism is generally in the lower greenschist facies. The Bay du Nord Group (Unit 3) is composed of highly deformed and metamorphosed metasediments which are converted to migmatite. This migmatite is intruded by numerous syntectonic granitoid dikes and posttectonically intruded by the North Bay Granite.

Around Dolland Pond, a poorly exposed unit of siltstone, sandstone and pebble conglomerate (Unit 4) is tentatively assigned a Silurian age. The unit contains a weak cleavage and has been metamorphosed in the lower greenschist facies. The unit has a synclinal structure.

The North Bay Granite (Unit 5) is a composite intrusion with medium grained, porphyritic, massive, biotite ± muscovite granites (subunits 5d, 5e, 5f, 5g, 5h and 5i) as the dominant rock type. The foliated granitoids (subunits 5a and 5c) contain a moderate to strong foliation which probably developed with the main fabric in the metasediments. Subunit 5b is dominantly leucocratic muscovite ± garnet ± biotite granite and pegmatite which have been strongly deformed possibly as the result of southwesterly overthrusting of the Ordovician units and the granitoids which lie to the northeast.

Unit 6 is the strongly mylonitized, northeast margin of the Burgeo batholith and forms only a small part of a northwest trending zone of mylonites over 100 km in length.

Unit 7 comprises four quartz-feldspar porphyry dikes which posttectonically intruded the North Bay Granite. These northerly trending dikes are more than 200 m in length and 10 to 15 m in width.

Minor scheelite-pyrite mineralization has been discovered east of Dolland Brook in sheared granite. Several major quartz veins were also found but have no apparent scheelite or fluorite mineralization. The scheelite mineralization corresponds with a lake sediment W anomaly.

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W.L. Dickson

GEOCHEMICAL SURVEYS OVER THREE TUNGSTEN ANOMALIES IN THE NORTH BAY BATHOLITH, SOUTHERN NEWFOUNDLAND

by

John McConnell
Geochemistry Section

Introduction

The discovery of tungsten and molybdenum mineralization in the Granite Lake area of the North Bay Batholith and tin mineralization in the Ackley Granite has spurred exploration interest. In view of this, the Geochemistry Section began a two-year project in 1982 of assessing the mineral potential of some granitoid terrains and evaluating the effectiveness of various exploration methods. Areas were selected on the basis of being mineralized and/or having lake sediment anomalies characteristic of mineralized granites. During the summer of 1982 soil, stream and rock sampling was done in the areas of Granite Lake (W-Mo), the southern portion of the Ackley Granite (Sn-Mo) and Francois (Pb-F-U-Mo) (McConnell, 1983).

Stream sediment and soil surveys were both found to be very effective in reflecting tungsten mineralization in the Granite Lake area.

During the past summer, the granite project continued by conducting geochemical surveys over three areas of the North Bay Batholith (Fig. 1). The areas were chosen because of their high values of W in lake sediment as indicated by recent data of Davenport and Butler (1982). No previous exploration for W has been reported from these areas although portions of all three were staked by a mining company following the release of the Davenport - Butler data.

Bottom Brook Anomaly

Bedrock and Glacial Geology

The most recent and detailed bedrock mapping in the area (N.T.S. 11P/16) is that of Dickson and Tomlin (1983). Outcrop in the 120 km^2 area is scarce. Where present, it consists of massive to foliated, biotite ± muscovite, medium to coarse grained granite considered of Silurian age. In some instances the granite grades into pegmatite. Examples of quartz veins both in outcrop and in float were observed, some slightly mineralized with pyrite.

Topographic relief is low and the area is covered by a moderate thickness of sandy till. Several ice-contact drift deposits and south-southeast trending eskers were noted. Direction of ice movement is considered to have been generally from north to south. Typically the ground is mantled by large angular boulders of granite similar in composition to that observed in outcrop. However, the compositions of the small lithic fragments contained within the soil profile, as noted during soil sampling, were predominantly meta-clastic and meta-igneous suggesting a considerable distance (5-10 km) of transport. This observation suggests that a significant component of the soil material sampled may also be derived from a source several kilometers to the north.

Geochemical Sampling and Analyses

Tungsten is the only element known to have anomalously high concentrations in lake sediments of the Bottom Brook area. The anomaly has two foci - a northern three lake sample cluster of approximately 40 g/t W and a looser 4 sample group ranging from 14 to 31 g/t W located about 5 km to the southwest. Two types of sampling - soil and stream sediment - were employed in an effort to better define the W anomaly. B-horizon soils were sampled at 400 m intervals along E-W lines spaced 1 km apart. Some closer spaced lines were sampled over the centre of the northern portion of the lake sediment anomaly. Well defined B-horizon material, mostly sand-silt in texture, was usually obtained. In total, 120 km of line were sampled and 332 samples collected. Conventional stream sediments numbering 246 were collected from the 120 km^2 of anomalous terrain. Active sediment was easily obtained in most instances. In addition, 25 samples of granitic bedrock, locally derived float and quartz veins were obtained.

Samples will be analyzed for W and Sn plus the suite - Cu, Pb, Zn, Co, Ni, Ag, Mn, Fe, Mo, F and Loss-on-ignition - and the data released on Open File as soon as possible.

Contribution to the Canada-Newfoundland co-operative minerals program 1982-84. Project funded by the Newfoundland Department of Mines and Energy and the Geological Survey of Canada.

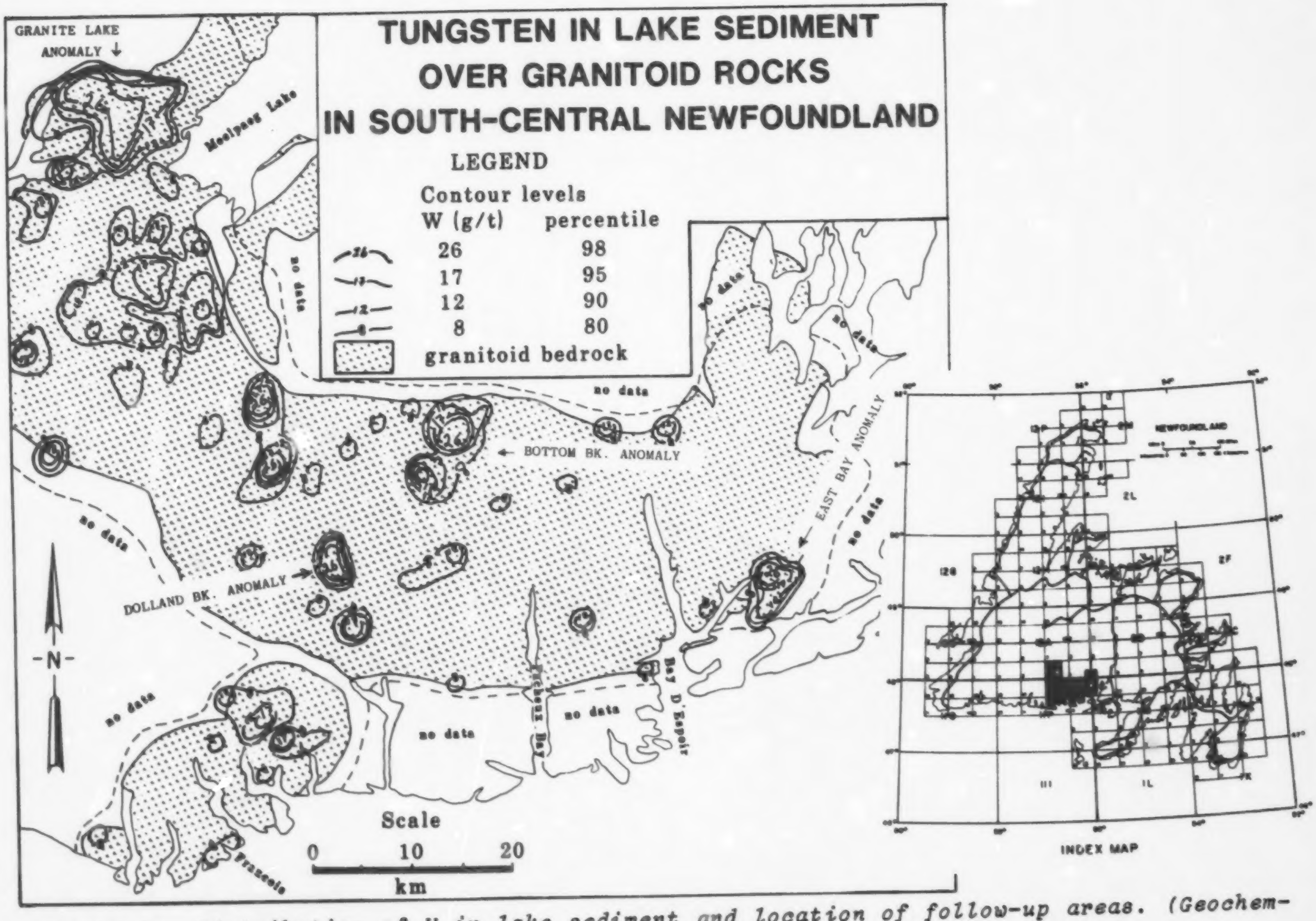
TUNGSTEN IN LAKE SEDIMENT
OVER GRANITOID ROCKS
IN SOUTH-CENTRAL NEWFOUNDLAND
LEGEND
Contour levels
W (g/t) percentile
26 98
17 95
12 90
8 80
granitoid bedrock
GRANITE LAKE ANOMALY ↓
Meelpaeg Lake
no data
no data
no data
no data
no data
no data
no data
no data
← BOTTOM BK. ANOMALY
EAST BAY ANOMALY
DOLLAND BK. ANOMALY
Facheux Bay
Bay D'Espoir
Francois
-N-
Scale
0 10 20
km
NEWFOUNDLAND
12B
2L
2F
11I
1L
1K
INDEX MAP

Figure 1: *Distribution of W in lake sediment and location of follow-up areas. (Geochemistry after Davenport and Butler, 1982.)*

East Bay Anomaly

Bedrock and Glacial Geology

The field area encompasses 30 km^2. Relief is rugged, outcrop abundant and till cover is thin to non-existent. The area straddles portions of N.T.S. sheets 11P/16 and 1M/13. The most recent geological mapping in 11P/16 is by Dickson and Tomlin (1983) and in 1M/13 by Colman-Sadd (1976). The central part of the anomaly is underlain by leucocratic North Bay Granite (Silurian) which irregularly intrudes psammites of the Riches Island Formation (Ordovician) toward the perimeter of the area. Immediately to the east of the sampling area disseminated molybdenite occurs in pegmatites, regarded as emanations from the North Bay Granite, which intrude psammites of the Riches Island Formation (Colman-Sadd, 1976).

Geochemical Sampling and Analyses

The high W contents in lake sediments (up to 30 g/t) are from lakes overlying the granite. Elevated values of Pb, Mo, Cu and Ag also are found in the lake sediments. Stream sediment samples (156) were collected across the area. Streams and sediments are abundant although drainage systems are poorly developed. The samples will be analyzed for the same suite of elements as described above for Bottom Brook.

Dolland Brook Anomaly

Bedrock and Glacial Geology

The field area (in southeastern N.T.S. sheet 11P/16) includes 30 km^2 and is everywhere underlain by the North Bay Granite. In general it is massive, unfoliated, medium grained, porphyritic, biotite ± muscovite granite. Previous to this summer no mineralization was known in the area. A small occurrence of pyrite in veins and disseminations in an altered quartz-feldspar-muscovite rock was located. Rock samples from this occurrence have trace amounts of a disseminated mineral which fluoresces bluish-white under ultra-violet light and which tentatively has been identified as scheelite.

This area was geologically mapped this summer at 1:50,000 by Dickson of the Department of Mines. No mapping of the quaternary geology has been done but features noted in the field indicate a southerly movement of ice. A thin to moderately thick blanket of sandy textured drift is present over virtually the entire area. Relief is low except across the deep valley formed by Dolland Brook.

Geochemical Sampling and Analyses

The lake sediment anomaly is defined by three lakes with W values ranging from 11 to 35 g/t. No other anomalous concentration of elements was noted. Samples (75) of B-horizon soil were taken at 400 m intervals along lines spaced 1 km apart. Stream sediments (128) were collected from across the area. Several rock samples of typical bedrock and mineralization were also taken. All samples will be analyzed for the element suite described above.

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J.W. McConnell

METALLOGENIC STUDIES OF GRANITE-ASSOCIATED MINERALIZATION IN THE ACKLEY GRANITE AND THE CROSS HILLS PLUTONIC COMPLEX, FORTUNE BAY AREA, NEWFOUNDLAND

by

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Also in Current Research, Part A, Geological Survey of Canada, Paper 84-1A.

Abstract

Cassiterite-bearing quartz-topaz greisen occurs in easterly trending veins and pods within the Ackley Granite, and as larger pods at the granite contact in the Sage Pond - Gisborne Lake area.

Minor anomalous radioactivity is associated with east-northeast trending fractures, and with aplite veins, near the roof of a riebeckite-bearing peralkaline granite which was emplaced late in the intrusion history of the Cross Hills Plutonic Complex.

Metallogenic models for granitoid mineralization in the Fortune Bay area suggest evolution of magmatic fluids during latest pluton emplacement and crystallization, with vertical rise and ponding of these fluids at or near the granite roof.

Introduction

This project is designed to develop metallogenic and exploration models for granite-associated mineralization in the Ackley Granite and Cross Hills Plutonic Complex, southeastern Newfoundland. It commenced in April, 1983. Field data collected during the 1983 field season will form the basis for a Ph.D. study by the author at Memorial University of Newfoundland.

Previous Work

Regional mapping in the area has been performed by Bradley (1962), Williams (1971), O'Brien and Nunn (1980), O'Brien et al. (1980a,b) and Dickson (1983).

Subeconomic aplite-pegmatite molybdenum deposits have long been known in the Rencontre area, and occur within the granite at the contact of a fine to medium grained porphyritic phase of the Ackley Granite with volcanic rocks of the Belle Bay Formation (Figure 1). The geology, geochemistry and exploration history of these deposits were described in detail by Whalen (1976, 1980, 1983).

Cassiterite-bearing quartz-topaz greisen veins have recently been identified by Esso Minerals Limited, and by the Newfoundland Department of Mines and Energy (Dickson, 1982; Dickson and Howse, 1982) in the Anesty Hill - Sage Pond area (Figure 1). These veins occur within a fine to medium grained, porphyritic marginal phase of the Ackley Granite and increase in concentration and size toward the granite contact (Dickson, 1983).

A peralkaline phase of the Cross Hills Plutonic Complex with minor anomalous radioactive zones has been identified by Saarberg Interplan, and anomalous assay values to a maximum of 285 g/t Sn, 133 g/t Ta, 2334 g/t Nb, 68 g/t U, 968 g/t Th, and 2% Zr have been reported by Hopfengartner (1982).

Work Performed - 1983 Field Season

(1) Quartz-topaz veins were mapped in detail along the Ackley Granite contact between Rabbit Pond and Gisborne Lake (Figure 2).

(2) Samples were collected from the quartz-topaz veins in the Sage Pond area (Figure 2) and from the molybdenite prospects at Motu, Ackley City, Crow Cliff - Dunphy Brook, and Wyllie Hill for geochemical analysis and for fluid inclusion studies (Figure 1). All known molybdenum occurrences in the Ackley Granite were examined and sampled, and samples were collected

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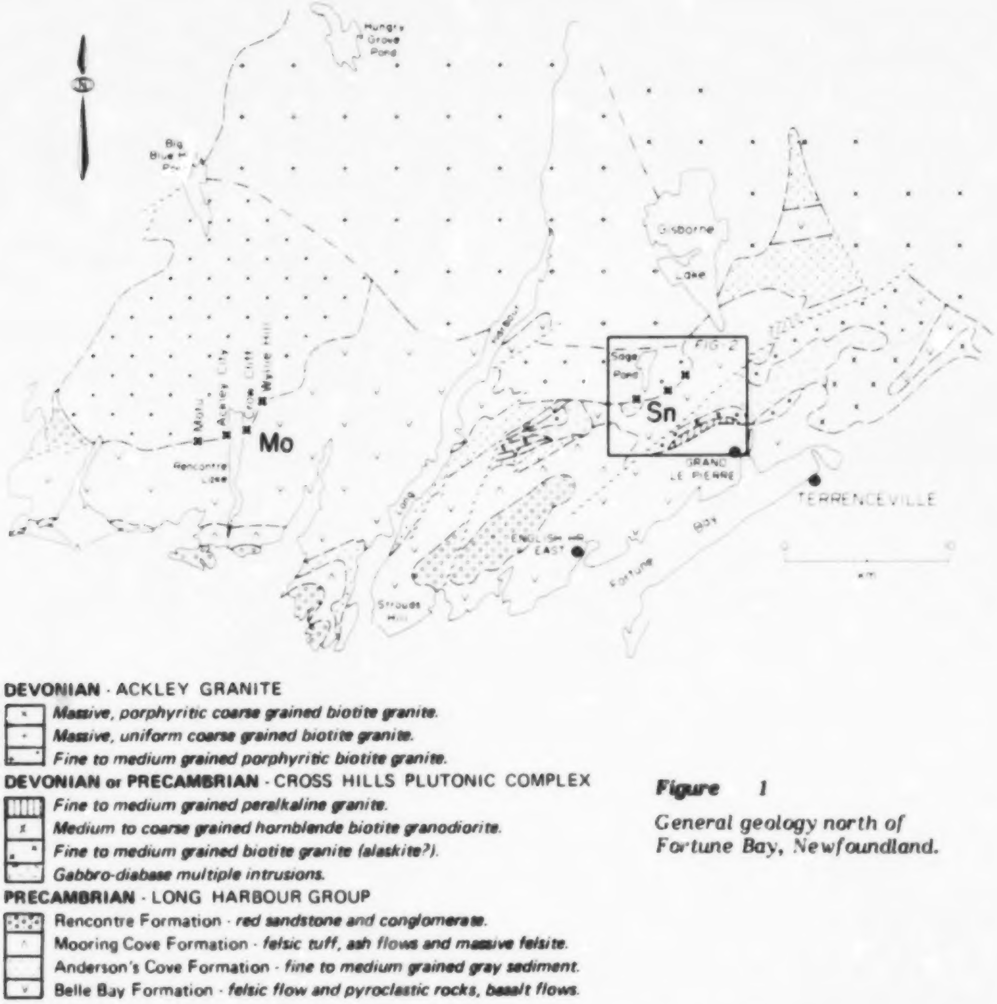
Hungry Grove Pond
Big Blue Hill Pond
Gisborne Lake
Sage Pond
FIG. 2
Sn
Moly
Ackley City
Crow Cliff
Wylie Hill
Mo
Rencontre Lake
Long Harbour
GRAND LE PIERRE
TERRENCEVILLE
ENGLISH HR. EAST
Strouds Hill
Fortune Bay
0
10
km
DEVONIAN · ACKLEY GRANITE
Massive, porphyritic coarse grained biotite granite.
Massive, uniform coarse grained biotite granite.
Fine to medium grained porphyritic biotite granite.
DEVONIAN or PRECAMBRIAN · CROSS HILLS PLUTONIC COMPLEX
Fine to medium grained peralkaline granite.
Medium to coarse grained hornblende biotite granodiorite.
Fine to medium grained biotite granite (alaskite?).
Gabbro-diabase multiple intrusions.
PRECAMBRIAN · LONG HARBOUR GROUP
Rencontre Formation · red sandstone and conglomerate.
Mooring Cove Formation · felsic tuff, ash flows and massive felsite.
Anderson's Cove Formation · fine to medium grained gray sediment.
Belle Bay Formation · felsic flow and pyroclastic rocks, basalt flows.

Figure 1

General geology north of Fortune Bay, Newfoundland.

from the Strouds Hill fluorite prospect at the south end of Long Harbour (Figure 1).

(3) The Cross Hills Plutonic Complex west of Grand Le Pierre and Precambrian volcanic rocks between the Cross Hills Plutonic Complex and the Ackley Granite were mapped at a scale of 1:15,000 (Figure 2). Several traverses were made over the Cross Hills Plutonic Complex to the east of Grand Le Pierre.

General Geology (Figure 1)

Plutonic rocks in the area of interest to the north of Fortune Bay intrude Precambrian subaerial metavolcanic and metasedimentary rocks of the Long Harbour Group (Williams, 1971; O'Brien and Nunn, 1980) in the Avalon terrane of the Newfoundland Appalachians (Williams and Hatcher, 1983).

The Long Harbour Group has been subdivided into four separate conformable formations (Bradley, 1962; Williams, 1971; O'Brien and Nunn, 1980). The stratigraphically lowest Belle Bay Formation is dominated by felsic ash flow deposits and epiclastic sediment with minor basalt flows, and is overlain by fine to medium grained sedimentary rocks of volcanic derivation belonging to the Anderson's Cove Formation. The overlying Mooring Cove Formation consists of interbedded silicic flows, felsite (commonly with peralkaline affinity; O'Brien, personal communication, 1983) and mafic flows. The Rencontre Formation, a red to purple fining-upward conglomerate to sandstone sequence, overlies the Mooring Cove Formation.

The Cross Hills Plutonic Complex intrudes the Belle Bay and Anderson's Cove Formations and consists of a complex mixture of diabase, gabbro, granodiorite, alaskite, and peralkaline granite, along with abundant xenoliths and roof pendants of silicic volcanic and mafic intrusive-extrusive rocks. The Cross Hills Plutonic Complex has not been dated: however, observation that gabbroic phases are cut by the Ackley Granite, and that there is a general lack of deformation and metamorphic effects has led to a consensus that these plutonic rocks are Devonian in age (Bradley, 1962; O'Brien and Nunn, 1980). The peralkaline granite phase of the Cross Hills Plutonic Complex is geochemically comparable to peralkaline silicic volcanic rocks of the Mooring Cove Formation (O'Brien, personal communication, 1983), and an age of Devonian or Precambrian may be inferred for both. The generally accepted stratigraphic ages for both units are depicted in Figures 1 and 2, pending resolution of this problem.

The Devonian Ackley Granite occupies an area of 3000 km^2 and has been divided into seven major units based on texture, mineralogy and geochemistry (Dickson, 1983), with the three most differentiated southern units having a silica content of greater than 72%. Fine grained, extremely differentiated marginal granite phases occur along and near the southern contact of the Ackley Granite, and exhibit strong trace element variation trends (Whalen, 1976, 1980, 1983; Dickson, 1983). The marginal phases hosting mineralization are fine grained to porphyritic, miarolitic biotite 'alaskite' granite, and minor occurrences of tuffisite are present. Quartz crystals and quartz-feldspar pegmatite patches are ubiquitous in the fine grained granite of the Rencontre area but are rare to absent in the fine grained granites in the Sage Pond - Gisborne Lake area. In the Fortune Bay area, the Ackley Granite cuts the Belle Bay and Anderson's Cove Formations as well as gabbroic rocks of the Cross Hills Plutonic Complex, and has been dated at about 355 Ma (Bell et al., 1977; Dallmeyer et al., 1983).

Geology, Sage Pond - Grand Le Pierre Area (Figure 2)

Volcanic Complex (Units 1 and 2)

The English Harbour volcanics (Bradley, 1962) south of the Cross Hills Plutonic Complex consist of massive to slightly fractured, light to dark rhyolite flows, welded ash flow deposits, breccias, and tuff (Unit 1a).

North of the Cross Hills Plutonic Complex, rocks mapped as belonging to the Belle Bay volcanic formation and the Anderson's Cove terrestrial metasedimentary formation (Bradley, 1962; O'Brien and Nunn, 1980) consist of a strongly foliated volcanic to volcano-sedimentary sequence (Unit 1b) composed of coarse, locally welded rhyolite breccias and tuff, waterlain tuff and sediment, slate, siltstone, quartz-sericite schist, diabase and basalt flows (Unit 1c). These rocks exhibit rapid lateral and vertical facies variations. They appear to be in fault contact with a massive banded to brecciated ash flow unit (Unit 1d) containing minor (<2%) disseminated and fracture-filling pyrite which occurs along the southern contact of the Ackley Granite. In the western part of the map area, purple-brown ash flow and fine tuff units (Unit 2) of the Mooring Cove volcanics (Bradley, 1962) overlie purple welded to nonwelded, massive to layered breccias, banded rhyolite, basalt flows, and minor siltstone.

Moderate to tight chevron folding of the layered tuff and siltstone and the ash flow banding occurs locally. This factor, coupled with the massive nature of the rocks, makes definitive structural and/or stratigraphic analyses of the volcanic sequence difficult. Bradley (1962) and O'Brien and Nunn (1980) suggested that large scale moderate to tight folding of the volcanic sequence occurred along an east-northeast axis.

The Anderson's Cove Formation is absent from the succession in this area, which suggests a local disconformity or unconformity.

Cross Hills Plutonic Complex (Unit 3)

Three main intrusive phases occur in the Cross Hills Plutonic Complex to the northwest of Grand Le Pierre.

3a: A fine to coarse grained diabase-gabbro unit intrudes Precambrian volcanic rocks and is composed of multiple intrusions of diabase and gabbro. Veining by fine to pegmatitic gabbro is common.

3b: A fine to medium grained, orange, 'alaskitic', miarolitic biotite granite intrudes the diabase-gabbro and locally intrudes volcanic country rocks. Extensive stoping of the gabbro-diabase is common and vertical subparallel biotite granite dikes trending 070° to 080° occur near the southern margin of the gabbro-diabase unit.

3c: A fine to medium grained purple-brown, miarolitic, riebeckite peralkaline granite occurs to the south and also above the biotite granite and has intruded the gabbroic and

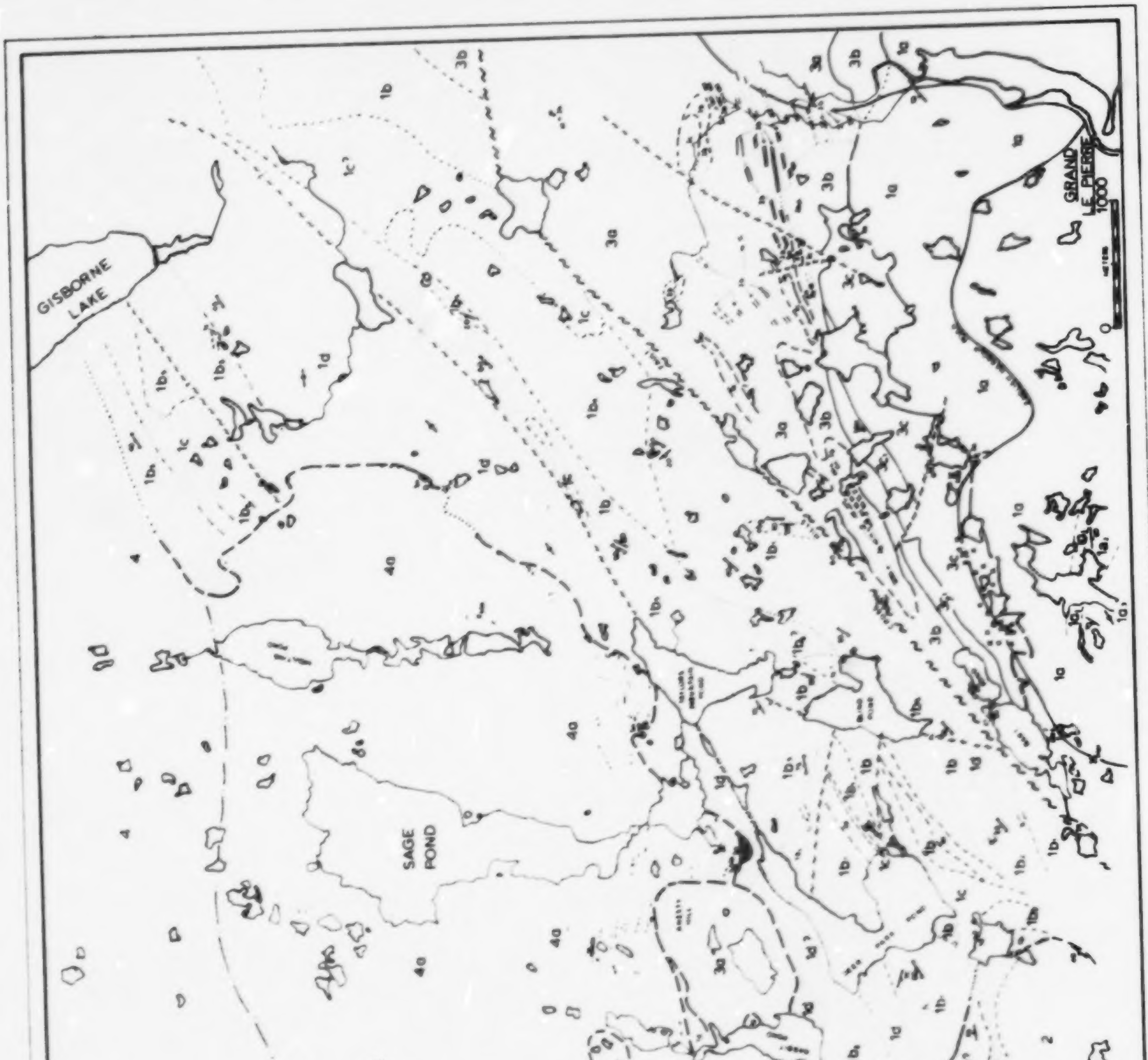
GISBORNE LAKE
SAGE POND
GRAND LE PIERRE
1000
1a
1b
1c
1d
2
3a
3b
4a

Figure 2: *Geology of the Grand Le Pierre - Sage Pond area, Fortune Bay, Newfoundland.*

LEGEND (Figure 2)

PLUTONIC ROCKS

DEVONIAN - ACKLEY GRANITE

▨ A *Quartz-topaz and/or quartz-muscovite greisen. Less than 10 by 2 m except where lettered.*

4a *Fine to medium grained, orange quartz-feldspar-porphyritic granite.*
4 *Medium to coarse grained equigranular biotite granite.*

DEVONIAN - possibly PRECAMBRIAN - CROSS HILLS PLUTONIC COMPLEX

3d *Very fine grained, red-brown aplite (?).*
3c *Fine to medium grained, miarolitic red-brown peralkaline granite;* **3c$_1$**, *orange to red-brown mottled aplite.*
3b *Fine to medium grained biotite (''alaskite?'') granite.*
3a *Diabase-gabbro multiple intrusions; can contain up to 30% veins and stockwork of 3b.*

VOLCANIC AND SEDIMENTARY ROCKS

HADRYNIAN - LONG HARBOUR GROUP

2 Mooring Cove Formation: *fine red-brown tuff and layered welded ash-flow units.*

1 Belle Bay Formation: *felsic pyroclastic and sedimentary rocks, felsic flows, and basalt flow.*
  1d *Rheoignimbrite: massive welded and layered ash-flow tuff, breccia, and nonwelded massive tuff.*
  1c *Foliated to massive vesicular basalt flow, agglomerate, and/or diabase.*
  1b *Foliated felsic breccia, ignimbrite, tuff and flow, minor welded units and sediment:* **1b$_1$**, *purple breccia and minor welded breccia and massive flow;* **1b$_2$**, *gray, locally welded breccia;* **1b$_3$**, *bedded to laminated fine to coarse sediment;* **1b$_4$**, *dark green, fine to medium grained, massive waterlain tuff or sediment* **1b$_5$**, *laminated to bedded gray, fine silicic tuff, phyllite and sericite schist; minor coarse breccia.*
  1a *Massive buff to green, nonwelded polylithic breccia, vesicular and/or feldspar porphyritic flow:* **1a$_1$**, *welded gray breccia with devitrification textures;* **1a$_2$**, *massive to bedded, medium to coarse, red and green sediment;* **1a$_3$**, *welded laminated ash-flow deposits.*

SYMBOLS

2% pyrite, sericite alteration, and gossanous	▨
1-2% disseminated and stringer pyrite, may be gossanous	▨
Hematite-limonite alteration	▨
>1000 g/t Sn assay; visible molybdenite and galena	X Sn, Mo, Pb
Malachite stain related to minor chalcocite and bornite	X Mal
Anomalous radioactivity, maximum 6 x background	X R
Bedding (tops known, unknown)	
Flow layering (inclined, vertical)	
Foliation (inclined, vertical)	

volcanic rocks. The riebeckite granite contains late fine grained veins, and tuffisite breccias related to gas-release from the crystallizing magma. Granophyric texture is common, and small granitic pegmatite patches are locally present. In the western part of the area mapped in detail, a mottled, orange-brown aplite unit (3c$_1$) with sharp vertical contacts occurs between the biotite granite and medium grained peralkaline granite. In the east, the contact between biotite granite and peralkaline granite is marked by a gradual color change. The northern boundary of the medium grained peralkaline phase is noted by a decrease of 30 to 50% in background total count radioactivity.

Three areas of peralkaline granite to the north and east of the main exposure occur topographically above biotite granite and probably form the upper portion of east-northeast trending biotite granite dikes. Red-brown aplite (Unit 3d) intrudes the Belle Bay Formation east of Deer Park Pond.

West of Grand Le Pierre, the Cross Hills Plutonic Complex appears to mark a phase of south-southeast/north-northwest crustal extension. Initial multiple intrusion of gabbro-diabase occurred, followed by stoping and intrusion of the gabbro and diabase by biotite granite. Differentiation to form a roofward or marginal peralkaline phase may have taken place in the larger silicic magma chambers.

Preliminary investigation of the Cross Hills Plutonic Complex east of Grand Le Pierre indicates a comparable history, with diabase being the more abundant mafic intrusive rock stoping into the volcanic rocks. East-northeast trending diabase dikes also commonly intrude the Precambrian volcanic rocks. Fine to medium grained biotite granite is the most common silicic lithology east of Grand Le Pierre, with minor patches of peralkaline granite noted. A medium to coarse grained hornblende-biotite granodiorite with abundant volcanic and diabase xenoliths is confined to the eastern portion of the complex; it has intruded the main diabase unit, and has locally been intruded by gabbro and thin aplite dikes. The relationship between the hornblende-biotite granite and the biotite granite has not been observed. Diabase, stoped by granite, occurs at the Southeast Bight Hills.

Ackley Granite (Unit 4)

The Ackley Granite consists of fine to medium grained, miarolitic, quartz-feldspar porphyritic biotite granite in its southern exposures (Unit 4a) and grades northward into a medium to coarse grained biotite granite (Unit 4). Phenocryst content averages from 10 to 20%. A coarse porphyritic phase with 40 to 50% phenocrysts is host to the greisen veins southeast of Moulting Pond. Topographic relief over the granite is gentle with little exposure, whereas the volcanic country rocks to the south form rugged topographic features and are well exposed.

The dip of the granite contact varies from vertical to shallow, with possible roof pendants present west of Anesty Hill and east of Moulting Pond.

Mineralization and Alteration, Sage Pond - Grand Le Pierre Area (Figure 2)

Volcanic Sequence

Extensive sericite alteration, commonly with 1 to 2% disseminated and fracture-filling pyrite and local zones of up to 5% pyrite, occur throughout the volcanic sequences in the area. Minor alteration with stockwork pyrite is a common feature marginal to the Ackley Granite and has been described from the molybdenite showings in the Rencontre area (Whalen, 1976); it probably resulted from late magmatic-hydrothermal processes associated with emplacement of the Ackley Granite. The pyritic alteration zones in the map area are in part related to the Ackley Granite. However, many of the pyritic zones may have a tectonic and/or synvolcanic origin. No base metal mineralization was observed; however, a potential exists for both gold mineralization and base metal mineralization within the volcanic sequence.

Peralkaline Granite - Cross Hills Plutonic Complex (Figure 2)

Throughout the peralkaline granite, zones of hematite and limonite stain occur with possible sericitic alteration and about 2 to 5% pyrite, and are developed over an area of 1000 by 200 m along the English Harbour road. Local 'veins' of gray-green intense sericitic alteration have been noted over a strike length of 30 m and a width of 3 m. These veins contain 1 to 5% disseminated and fracture-filling pyrite with trace amounts of galena. The alteration is related to late east-northeast fractures and breccia zones in the pluton.

A zone of anomalously radioactive patches from 2 to 5 times background, trending 070°, was noted in the granite over a strike length of 100 m southeast of Bart Pond. Individual anomalous patches are less than 2 by 0.5 m, and are related to hairline fractures near the granite roof. Several 2 m diameter areas of anomalous radioactivity up to 6 times background were noted elsewhere and are associated with hairline fractures or late aplitic veins in the peralkaline granite.

Traces of chalcocite with minor malachite stain were noted in two separate, late crosscutting quartz veins (maximum width 1 m) in the granitic phases of the Cross Hills Plutonic Complex.

A general metallogenic model suggests marginal and roofward concentration of volatile and ore elements in a silicic magma chamber with potential mineralization (Nb, Zr, Sn, Th, F?) at or near the roof contact either as aplite or pegmatite sheets, or as veins in postcrystallization fracture zones. A possibility exists for economic mineralization in late crystallizing differentiates.

Quartz-Topaz Veins in the Ackley Granite

The main concentration of white, medium to coarse grained quartz-topaz veins occurs between Rabbit Pond and Gisborne Lake at and near the south contact of a fine to medium grained porphyritic marginal phase of the Ackley Granite. Quartz-topaz veins have been noted as far west as Long Harbour and have been observed within the granite up to 3 km from the contact. They increase in concentration and size southward, with the largest quartz-topaz outcrops occurring at convex undulations of the granite contact. Veins are podiform-elongate with a predominant easterly trend (080° to 110°) and are generally less than 10 by 2 m. They form knobs of outcrop or suboutcrop in weathered granite till or in areas of weathered granite subcrop.

Subparallel quartz-topaz ± pyrite ± hematite ± molybdenite ± fluorite vein swarms (fracture-fillings to 3 m wide veins) underlie massive quartz-topaz outcrop (50 by 6 m) at the Esso Minerals Ltd. drill site southwest of Moulting Pond. Sericitization and bleaching (± pyrite) of the host orange-red granitic quartz-feldspar porphyry is limited to within 1 m of individual veins and is generally narrower than vein width. Gray-green muscovite-quartz-topaz greisen commonly occurs marginal to massive quartz-topaz but can occur as individual veins. Fine fracture networks are common in the unaltered granite host and minor disseminated pyrite may be present in granite near the veins. Intense fracture networks with pyrite coatings are present in the volcanic rocks adjacent to the granite contact.

South of Anesty Hill, massive quartz-topaz rock (± pyrite ± fluorite with occasional grains of molybdenite) outcrops over an area of 200 by 60 m within a convex south lobe of the granite. Gently dipping layering (20° to 40° south), defined by variation of topaz and quartz content and of grain size, suggests an area where fluorine-rich fluids were ponded near the granite roof. Rhyolite outcropping immediately south and west of the Anesty quartz-topaz body is strongly sericitized, suggesting that the greisen zone plunges to the south and west under the rhyolite.

A generalized model is envisaged in which fluorine ± tin-rich magmatic fluids evolved from a rapidly crystallizing marginal granite phase and rose along east trending fractures in consolidated granite to collect in embayments at the granite margin and roof (see Dickson, 1983). A potential exists for large tonnage, low grade stockwork deposits in addition to high grade vein and massive greisen deposits.

Comparable mechanisms involving extreme differentiation, roofward migration of molybdenum-rich magmatic fluids, and collection of these fluids in pockets at the granite roof have been proposed for the origin of the molybdenite deposits in the Rencontre area (Whalen, 1976, 1980, 1983; Dickson, 1983).

Minor Copper Occurrences, Grand Le Pierre Area

Minor malachite stain associated with chalcocite and/or bornite mineralization in fractures was noted (1) in sheared rhyolite breccia in the Cross Hills Fault zone northeast of Bart Pond (Figure 2); (2) in rhyolite breccia approximately 5 m west of the contact of the granodiorite phase of the Cross Hills Plutonic Complex on the Grand Le Pierre - Terrenceville road; and (3) in rhyolite on the west side of the English Harbour road at the southwest limit of the area mapped (Figure 2).

Other Occurrences of Alteration and Mineralization, Fortune Bay Area

(i) Several beryl crystals up to 3 by 1 cm were noted in a 50 by 20 cm quartz pocket in the fine grained phase of the Ackley Granite to the southeast of Big Blue Hill Pond (UTM 343 967, 1M/14).

(ii) Three molybdenite flakes (up to 1 cm) were noted in a roadside quartz vein on the east margin, and fluorite veinlets were observed near the western margin of the Berry Hill Stock on the Burin Peninsula.

(iii) Silicified and/or sericitized zones (in fine grained Precambrian tuff and sediment) with 1 to 5% disseminated and/or stringer pyrite were noted over a width of up to 70 m on the Monkstown road (east of the Burin Highway). Minor fine grained chalcopyrite may be present locally. Other pyrite occurrences are present on the Burin Highway. These may represent synvolcanic hydrothermal exhalative or subvolcanic epithermal processes, and a potential for base metal and/or gold mineralization is evident.

A blue phosphate-rich mineral, tentatively indentified as lazulite, was noted in a 50 by 10 m quartz-specularite vein at UTM 888 877 on NTS 1M/9, immediately north of the Monkstown Road.

(iv) Molybdenite occurrences reported at Hungry Cove Pond and at Spout Brook, and a Mo-Bi showing at Big Blue Hill Pond (Anderson, 1965) could not be located. A vertical quartz vein with maximum dimensions of 1.5 m by 5 cm containing minor pyrite and possible trace wolframite was observed at the Big Blue Hill Pond locality.

(v) Swarms of narrow, subvertical quartz-muscovite greisen veins were noted at two localities southeast of Big Blue Hill Pond (UTM 356 937 and 364 948; 1M/14); grab samples analyzed 1150 and 130 g/t tin, respectively. Veins observed have a maximum dimension of 30 cm by 10 m and trend 060° to 070°. A maximum vein density is 2 to 3 per metre.

Acknowledgements

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J. Tuach

ACKLEY BATHOLITH GRAVITY SURVEY

by

H.G. Miller[1]

Introduction

Gravity data were collected in September, 1983 in association with the geological mapping of the Ackley pluton and surroundings described elsewhere in this volume (Tuach, 1984). The objective of the gravity mapping was to obtain gravity data for use in modelling the subsurface configuration of this pluton. The models obtained from the gravity data are to be used in studies on the metallogenic evolution of the area.

Fifty-two gravity stations were occupied along three traverses, two using helicopter access across the Ackley batholith and the Cross Hills plutons and the third along the existing road network to tie the other two profiles together. The station spacing was approximately 5 km along the two major profiles (Figure 1) and 1 km along the road profile. The preliminary interpretation of the data for the traverse across the Ackley Batholith is presented here.

The gravity data were collected using a Lacoste-Romberg land gravity meter. Elevations were obtained from barometric altimeters using survey methods appropriate to the local elevation control network (Miller and Deutsch, 1976). Positions were scaled from 1:50,000 topographic maps. The survey was tied to the Canadian national gravity network through the use of the national network base station at Terrenceville.

The Bouguer anomaly was calculated at each station using the appropriate base gravity value, the 1968 International Gravity Formula, and a crustal density of 2.67 g cm^{-3}. The anomalies calculated by this method are absolute Bouguer anomalies which can be compared with the previously published anomalies on the older anomaly maps produced by the Dominion Observatory (Weaver, 1968) by subtracting approximately 6.2 mGal from the older Weaver data. This adjustment is necessary since the anomalies on the older maps were computed using the 1931 International Gravity Formula and the old base network.

Interpretation

Weaver's data were collected with a mean station spacing of 13.5 km. The Ackley Batholith is easily recognized on these maps (Weaver, 1967, 1968) as a region of gravity anomalies significantly lower than those of the surrounding area. The lowest anomalies occur over the central portion of the pluton with positive anomalies occurring to the northwest and southeast of the pluton.

The present survey was undertaken to provide a more detailed set of data along a profile perpendicular to the regional geological trend. These data were modelled to ascertain the thickness and the rock density distribution within the pluton. The results of the modelling are to be incorporated into the interpretation of the evolution of the mineral deposits found on the southeastern side of the pluton. The gravity analysis is to be accompanied by an interpretation of the aeromagnetic data for the area.

To date the gravity data have been reduced and a preliminary model of the gravity field has been obtained using rock densities typical of other Newfoundland granites, gneisses and volcanics. More detailed and precise interpretation will be possible when the densities and magnetic susceptibilities of samples from the area are analyzed.

The major conclusion from the study is the affirmation that the maximum thickness of the pluton is in its southeast corner. The maximum thickness calculated using the density chosen is 9 km (Figure 2). The calculated thickness is sensitive to the density used for the pluton. Should subsequent studies indicate that the density must be modified, the geometry of the body will remain the same but the absolute thickness will vary from that in the model. The analysis of the magnetic data will permit a more detailed analysis of zonation within the pluton.

Contribution to Canada-Newfoundland co-operative minerals program 1982-84. Project partly funded by the Geological Survey of Canada.

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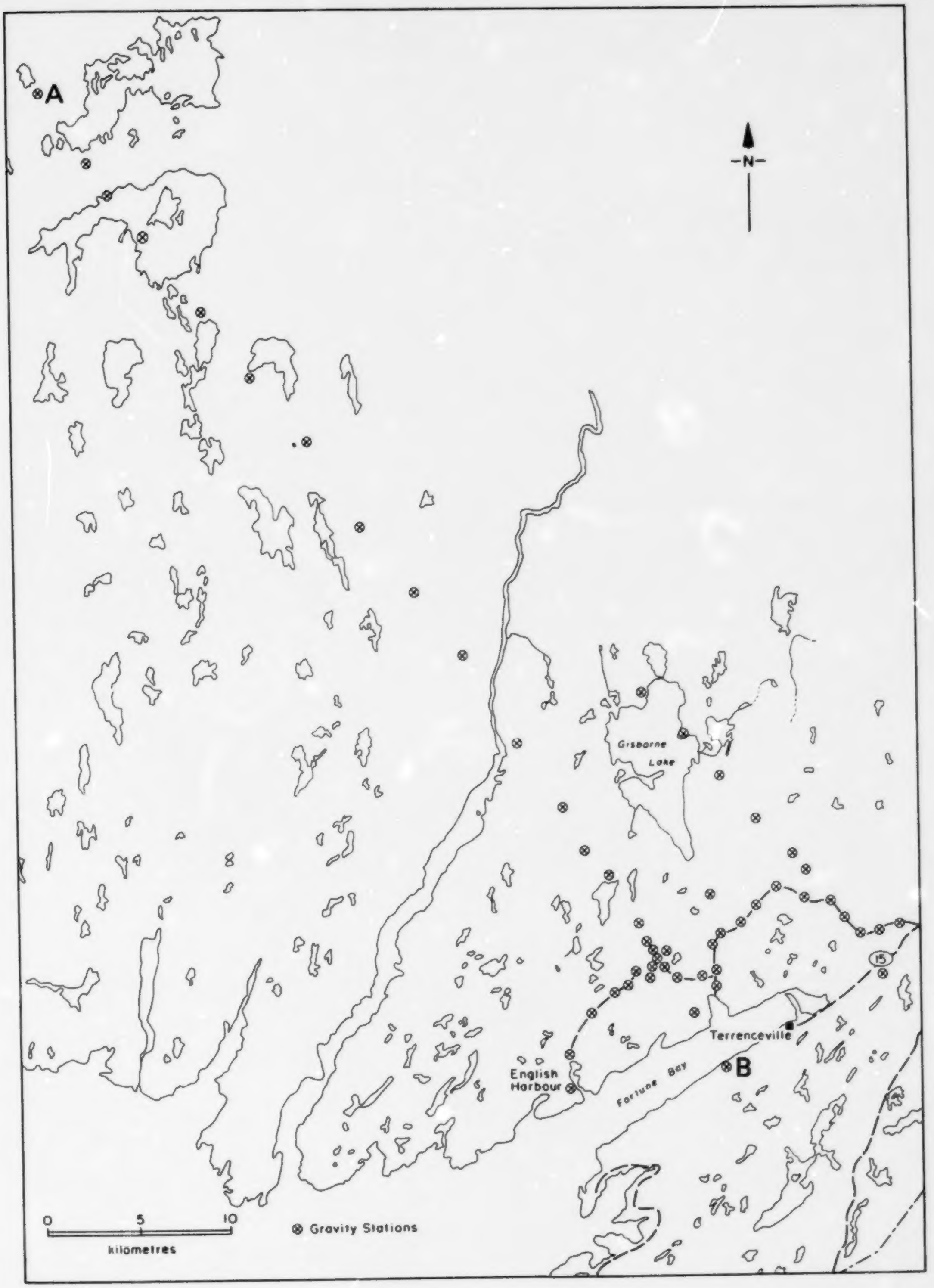
A
N
Gisborne Lake
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Figure 1: *Ackley gravity survey.*

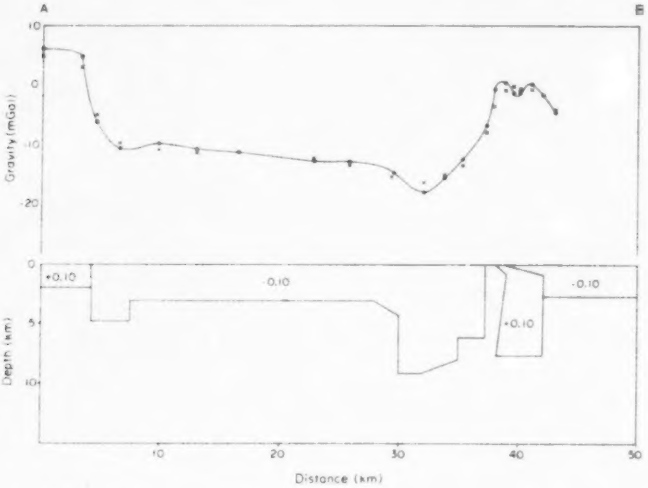

Figure 2: *Gravity profile.*

The determination of the subsurface configuration of the pluton from the combined gravity and magnetic analysis will present a model which will be combined with the metallogenic studies to explain the presence and evolution of the tin and molybdenum deposits associated with the pluton.

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COMPUTER-AIDED ANALYSIS OF LITHOGEOCHEMICAL DATA FROM NEWFOUNDLAND GRANITES AND ITS ROLE IN MINERAL EXPLORATION

by

P.H. Davenport, J. Tuach and W.L. Dickson
Geochemistry, Mineral Deposits and Newfoundland Mapping Sections

Introduction

Geochemical indicators have been used by many workers to distinguish mineralized from barren granitoid plutons, e.g. Tischendorf et al., 1978; Mutschler et al., 1981. Some of these geochemical indicators have been regarded as of local or regional value, while others have been touted as having global significance. The first large scale attempt at assessing the mineral potential of some Newfoundland granitoids through their geochemistry was that of Strong et al. (1974). Subsequently, three studies have been made with a more systematic sampling approach by Elias (1980) of 14 plutons in the Bay D'Espoir area, by Dickson (1983) of the Ackley Granite, and by Blackwood and Green (1982) of the Middle Ridge Granite. In addition, there are several studies in progress which include granitoid geochemistry.

Granite Geochemistry Data File

To fully utilize these geochemical data to assess mineral potential, they are being organized into a computer file containing field observations as well as geological and chemical information. Currently, this file contains data from 1243 samples collected from 21 plutons. For all samples, the following information is recorded: sample number, pluton, U.T.M. coordinates, rock type, age, physical characteristics (color, grain size, texture, banding, alteration), fabric, composition of mafic minerals, presence or absence of sulfides, garnet, tourmaline, beryl, fluorite and muscovite, as well as major element data. The trace element suite for most samples is Li, Be, F, V, Cr, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Mo, Ba, Pb, Th and U. Sn and W have been determined on selected samples.

Uses of The Data File

Once the data are assembled into an organized computer file, it becomes very easy to apply to Newfoundland granites "geochemical indicators" of mineralization developed by other workers elsewhere. It is apparent, for example, that the concept of S and I type granites is not readily applicable to the granitoids of southeastern Newfoundland (e.g. Dickson, 1983), so this concept is of little use as a guide to mineralization in the area. In addition, it is easy to carry out various multivariate statistical procedures on the data to gain a better understanding of the interrelationships present and, hence, to gain some insight into geochemical processes. Finally, computer graphics can be used to examine the data through both standard petrological diagrams and areal plots of the data and derived variables.

An illustration of the application of the analysis of a geochemical computer data file to mineral exploration can be provided for the Ackley Granite. This was systematically sampled on a 2 km x 2 km grid and geologically mapped by Dickson (1983). The geology and known mineral occurrences in the Ackley Granite are shown in Figure 1, and plots of Sr and Ba against SiO_2 for units 14, 14 a and 14b (which contains the known mineral prospects) are shown in Figures 2a and 2b. A large proportion of the samples in these units show moderate to extreme depletion in both Sr and Ba over an SiO_2 range of about 75 to 79%. Enrichments in F, Rb, U and Th in units 14, 14a and 14b relative to the rest of the granite are also apparent over the same range in SiO_2. To examine the spatial chemical variations within the granite, the data from all 357 sites were computer-plotted and hand-contoured using arbitrary contour levels derived from cumulative frequency plots. The distributions of Ba and Sr are shown in Figure 3, from which it is clear that the areas of extreme depletion of these elements are largely centered on the mineral occurrences in units 14a and 14b. Areal plots of a number of other major and trace elements and various ratios showed a variety of geochemically significant trends.

To try to summarize the trends of the 11 oxides, 20 trace elements and a number of element ratios, R-mode factor analysis was carried out. This mathematical procedure is also known as principal components analysis; in this application, the tech-

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Project funded by the Newfoundland Department of Mines and Energy.

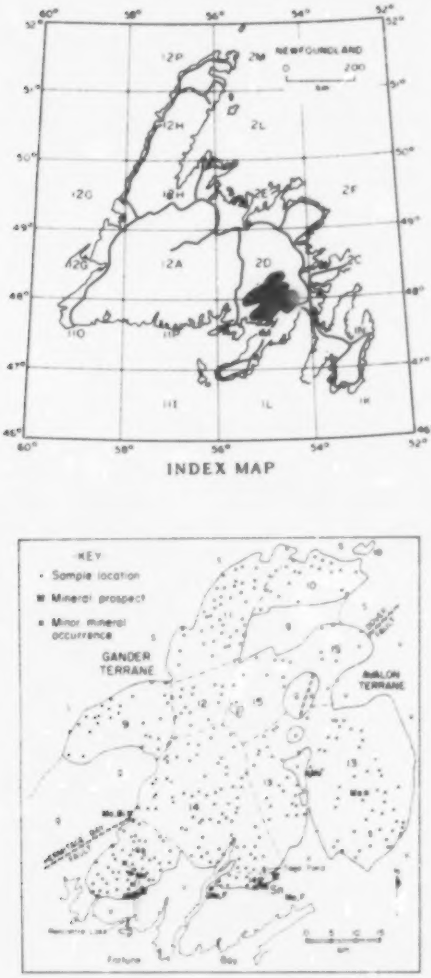


Figure 1: *Index map and geological map of the Ackley Granite (after Dickson, 1983) showing the main textural units of the granite, mineral occurrences and sample sites.*

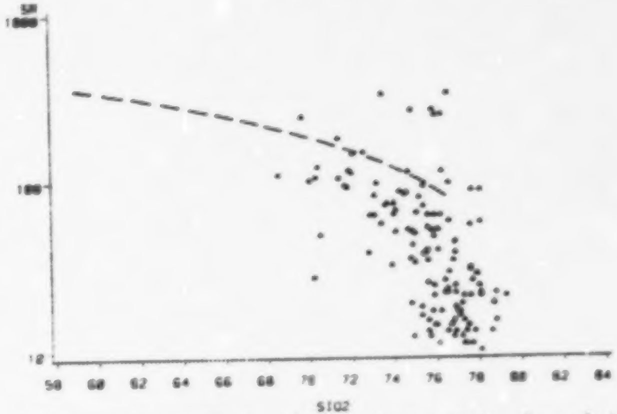


Figure 2a: *Plot of Sr (log scale in g/t) against SiO_2 (in percent) for units 14, 14a and 14b of the Ackley Granite. Dashed line is the best fit line for units 9-13 and 15.*

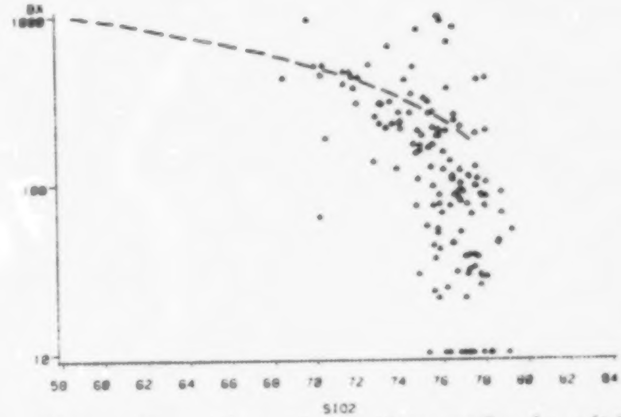


Figure 2b: *Plot of Ba (log scale in g/t) against SiO_2 (in percent) for units 14, 14a and 14b of the Ackley Granite. Dashed line is the best fit line for units 9-13 and 15.*

nique is used to produce a relatively manageable number of variables from the 31 major oxides and trace elements. The first factor, or principal component, is a linear combination of these 31 variables chosen to account for more of the variance of the data than any other linear combination. The second factor is then chosen to account for more of the remaining data variance than any other combination of variables and so on. Each factor is chosen to be independent of (or orthogonal to) the previous factors. In theory a number of factors equal to the number of variables can be extracted, but the purpose of the method is to account for most of the observed variation by means of a few (perhaps four to six) factors. The calculation of the factors is an objective mathematical process, but the selection of the model to use (i.e. the number of factors) is subjective. Table 1 gives an example of a four-factor model for the Ackley Granite. The importance of the contribution of each oxide or element to the factor is given by the factor loading. This may vary from -1.0 to 1.0 and can be thought of as a regression coefficient. In Table 1, only elements with loadings of a magnitude greater than 0.5 for any element are listed for each of the four factors. The first and second factors account for over 50% of the total data variance and are the most readily explained geologically. Factor 1 can be related to normal geochemical trends in a differ-

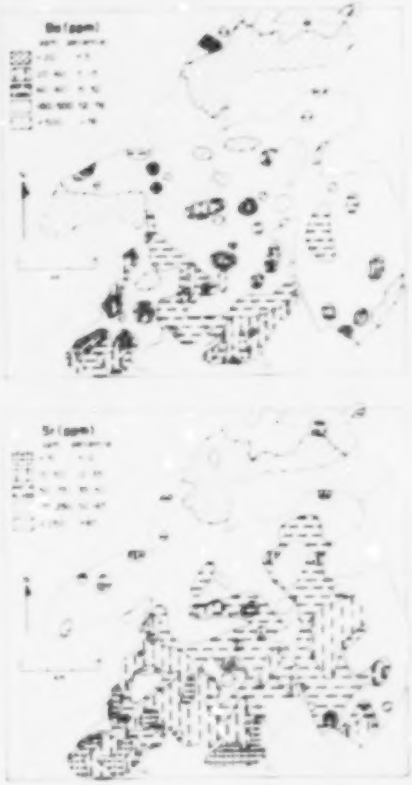


Figure 3: *Distribution of Ba and Sr in 357 samples of the Ackley Granite. The data were hand-contoured and no smoothing was applied.*

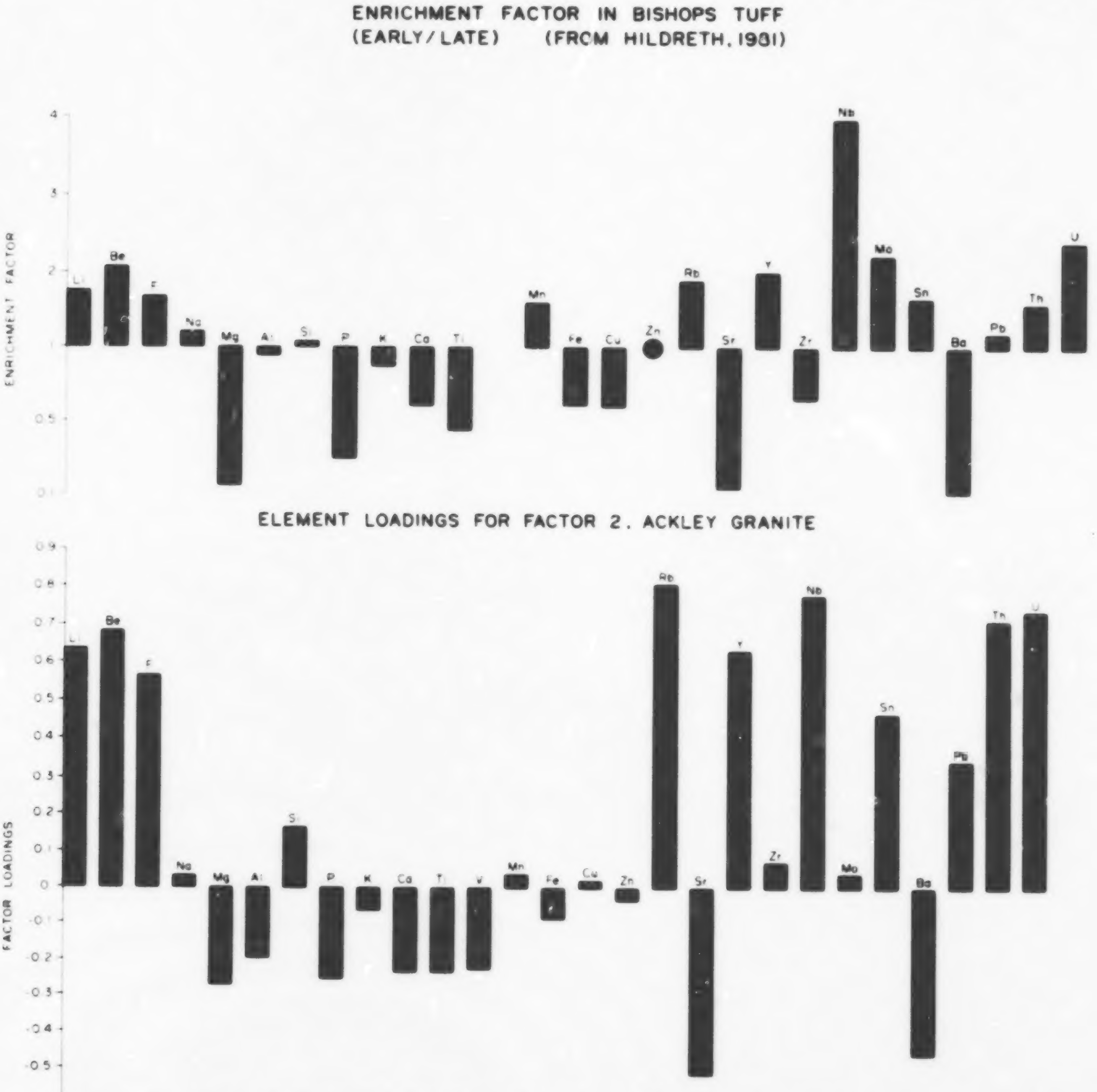
entiated comagmatic suite of rocks, with SiO_2 varying antipathetically with MgO, Al_2O_3, FeO, Fe_2O_3, TiO_2, MnO, P_2O_5 and the trace elements V, Sr, Ba and Zn. This factor accounts for over 38% of the total "geochemical variance" in the granite.

Factor 2 is a combination of the lithophile trace elements Nb, Rb, U, Th, Y, Be, Li, Sn, together with Ga and F. This factor also has negative loadings on Sr and Ba. Concentration of these elements is typical in the upper part of a silicic magma chamber (e.g. Hildreth, 1981; Strong, 1980), with depletions of Sr and Ba. In fact, in a qualitative way, it is possible to construct a pseudo-enrichment/depletion diagram to compare with the relative enrichment diagram for the Bishops Tuff of Hildreth (1981). The correspondence in sense of the elements' variations is striking (Figure 4). The other two factors in this model are of less interest.

From the element loadings a factor score can be calculated for each sample. Thus, for factor 1, a low, negative score will be generated for a sample high in SiO_2 and low in MgO, TiO_2, etc. (i.e. a highly differentiated granite), whereas high positive scores will be assigned to more mafic samples. Similarly, for factor 2, high positive scores will result in samples high in lithophile elements, Ga and F, and low in Ba and Sr. If the geochemical significance of factor 2 is related to the concentration of these elements at the top of the granite body, the high positive scores should form a coherent pattern which would delineate this zone of concentration.

Table 1: *Four-factor model for the 357 grid samples from the Ackley Granite. The factor model was subjected to a varimax rotation. Only factor loadings with a magnitude greater than 0.5 have been listed.*

	Factor 1	Factor 2	Factor 3	Factor 4
	SiO_2 (-0.88)	Nb (0.81)	Pb (0.76)	Na_2O (0.79)
	MgO (0.89)	Rb (0.79)	K_2O (0.60)	
	TiO_2 (0.88)	U (0.76)		
	P_2O_5 (0.87)	Th (0.73)		
	V (0.84)	Y (0.72)		
	MnO (0.82)	Be (0.64)		
	Al_2O_3 (0.81)	Ga (0.58)		
	Sr (0.71)	Li (0.55)		
	Ba (0.69)	F (0.55)		
	Zn (0.68)	Sn (0.54)		
	Zr (0.57)	- Sr (-0.55)		
	FeO (0.54)	- Ba (-0.57)		
	Fe_2O_3 (0.51)			
% of variance:	38.3	12.9	5.8	4.9


ENRICHMENT FACTOR IN BISHOPS TUFF
(EARLY/LATE) (FROM HILDRETH, 1981)

ELEMENT LOADINGS FOR FACTOR 2. ACKLEY GRANITE

Figure 4: *Plot of factor 2 loadings for the Ackley Granite (below) for 28 of the 31 chemical variables (FeO, Fe_2O_3 and LOI omitted) compared with enrichment/depletion plot for Bishops Tuff (Hildreth, 1981). The factor loadings are correlation coefficients of the variables with the factor; elements having a large positive loading (0.5-1.0) contribute strongly and positively to the factor; loadings between 0.5 and -0.5 indicate modest to minimal contributions, and loadings in the range -0.5 to -1.0 are for those elements with a strong negative contribution. The correspondence in sign and relative magnitude between the factor 2 loadings for the Ackley Granite and the enrichment (+) and depletion (-) factors for the early (top of magma chamber) and lower (deeper in magma chamber) units of the Bishops Tuff are striking, and suggest similar processes were operative in both magma chambers.*

The factor scores from factors 1 and 2 are plotted in Figure 5. The following points are noteworthy:

(1) The factor scores do show coherent patterns.

(2) Factor 1 scores are lower (i.e. SiO_2 is higher and Al_2O_3, MgO, TiO_2, etc. are lower) in the southeastern half of the pluton. This may reflect an inherited compositional difference in source material since the two parts of the granite as defined by factor 1 are separated by a line which lies close to the projection of the Dover - Hermitage Bay fault zone, with the Gander Terrain lying to the northwest and the Avalon Terrain to the southeast.

(3) Factor 2 scores show a crosscutting north-south trend. High values of this factor (indicating enrichment in Sn as well as Nb, Rb, U, Th, Y, Be, Li, and F) surround the known Sn-bearing greisen zones, and extend in a west-northwest trend to include the Mo-Bi showing at Big Blue Hill Pond (line A-B in Figure 5). Small greisen veins were discovered within the central part of this trend near site C (see Tuach, *this volume*).

(4) The area of Mo showings west of Long Harbour shows only moderately high scores for factor 2, suggesting that this southwestern lobe of the granite is different from the Sn-bearing south-central margin of the granite. The mineralization in this southwestern lobe is not Sn-bearing, but it is reflected by a halo of Sr and Ba depletion. There are also differences in F content of the two marginal phases (unit 14a).

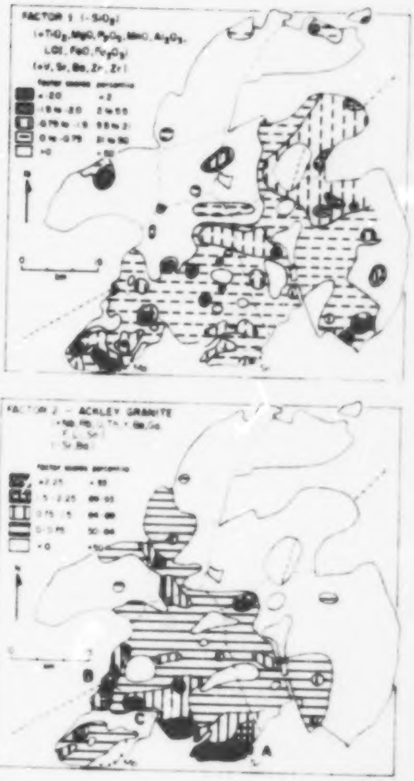


Figure 5: *Distribution of factor scores (hand-contoured, no smoothing) in the Ackley Granite.*

Conclusion

This simple example of a computer-aided analysis of the lithogeochemical data from the Ackley Granite shows the potential power of this approach. Such an analysis presupposes the existence of a sample suite from a well designed field sampling scheme, and the organization of the data in a computer file.

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P.H. Davenport

J. Tuach

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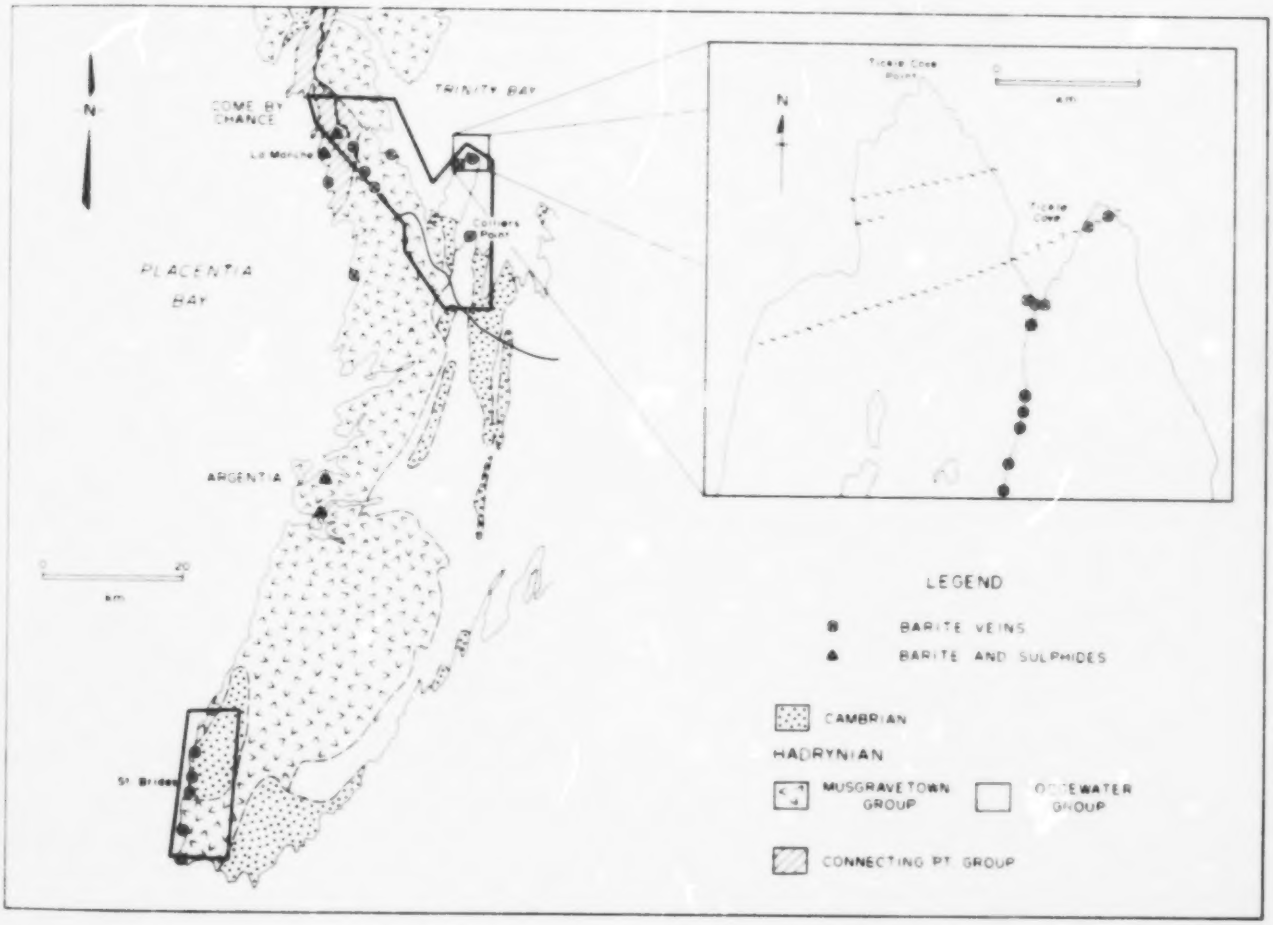
BARITE EVALUATION IN THREE AREAS OF SOUTHEASTERN NEWFOUNDLAND

by

A.F. Howse and C.J. Collins*
Mineral Deposits Section

Introduction

An evaluation of the barite potential of the western Avalon Peninsula continued during the summer of 1983. This assessment consisted of a regional stream sampling and prospecting program in two main areas of interest (Figure 1): (1) the eastern section of the Avalon Isthmus between Southern Harbour railway station in the north and Normans Cove in the south, an area underlain mainly by late Precambrian


N
COME BY CHANCE
TRINITY BAY
La Manche
Colliers Point
PLACENTIA BAY
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Tickle Cove
LEGEND
BARITE VEINS
BARITE AND SULPHIDES
CAMBRIAN
HADRYNIAN
MUSGRAVETOWN GROUP
GROUP
CONNECTING PT. GROUP

Figure 1: *Western avalon showing project areas; insert shows barite occurrences on Bellevue Peninsula.*

Contribution to the Canada-Newfoundland co-operative minerals program 1982-84. Project financed by the Newfoundland Department of Mines and Energy and the Geological Survey of Canada.

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volcanic and sedimentary rocks, and (2) the St. Brides area of the Cape Shore, from Cape St. Mary's to Angels Cove, an area underlain by Hadrynian and Lower Cambrian sedimentary rocks. Prospecting along streams was carried out in conjunction with sampling. The stream sediment survey on the Avalon Isthmus was coordinated with a similar project in an adjacent area by Butler and Davenport (see report in this volume), who carried out geochemical follow-up of lake sediment anomalies that had been identified by a 1975 regional survey (Davenport et al., 1975). The results will be made available as an open file release after the analyses are completed.

A major sampling program was also carried out on known fluorspar veins in the St. Lawrence area of the Burin Peninsula, with particular emphasis on those veins known to contain associated barite. Forty veins were examined and sampled.

Isthmus of Avalon

A stream sediment survey was done along the eastern section of the Avalon Isthmus between Southern Harbour railway station in the north and Normans Cove in the south. The regional geology of the area was mapped and described by McCartney (1967). The oldest rocks there are marine sediments and tuff of the Connecting Point Group, which underlie the northwest part of the study area. Basaltic and rhyolitic volcanics of the Bull Arm Formation unconformably overlie the Connecting Point Group, and comprise the central and northeast section of the survey area. The Bellevue Peninsula and Collier Point are underlain by sedimentary rocks (mainly green arkose, siltstone and minor conglomerate) of the Hodgewater Group. South of the Bellevue Peninsula and west of Chapel Arm, the survey area is underlain by quartzite of the Random Formation and Lower Cambrian red and green shales and nodular limestone.

Barite veins are widely distributed throughout the area and were the subject of a Department Mines and Energy survey in 1982 (Howse and French, 1983). The best known vein, at Collier Point, is of commercial interest and is presently being developed, while the potential of other areas (notably the Bellevue Peninsula) for hosting veins of high grade barite is being recognized. All documented occurrences of barite, with the exception of some minor showings exposed in road cuts, are on the coast.

The 1983 stream sediment survey represents an effort to assess the barite (and base metal) potential inland. Prospecting for mineralized float and outcrop was also an integral part of the stream traverses.

395 samples were collected, as uniformly as possible, at approximately 400 m intervals along the streams. Duplicate samples, for field control purposes, were taken at every twentieth sample site. A special effort was made to collect only active silt and to avoid, where possible, organic-rich material. The samples were dried and sieved to minus 80 mesh (<180 um) and are being analyzed for Ba, Sr, Cu, Pb, Zn, Ag, Fe, Mn and L.O.I..

Mineralization

A new barite-galena vein was discovered in sedimentary rocks of the Connecting Point Group about 2 km east of Little Southern Harbour. The vein is located midway between the east shore of Little Southern Harbour and the Trans Canada Highway immediately upstream from the water supply dam (approximate UTM grid reference: 5288700 N, 279850 E). The vein, which appears to lie along a brecciated fault zone, strikes northeasterly and is nearly vertical. It has a maximum width of about 80 cm but appears to pinch out rapidly on both sides of the stream in which it is exposed. The barite and associated galena occur as pods, blebs and stringers within the fractured and brecciated host rock. One such pod, about 20 cm in width but wedging at depth, contains an estimated 60% barite and 40% galena. Calcite also is present as a minor constituent. The galena usually occurs as coarse crystal aggregates in a barite and calcite gangue, but isolated patches were also observed. The mineralization could not be traced beyond the banks of the stream because of overburden.

Five grab samples of the mineralization were taken for assay and the results are shown in Table 1 below.

Table 1: *Assay analyses of samples taken from the Little Southern Harbour vein.*

Sample No.	Ba (%)	Cu (ppm)	Zn (ppm)	Pb (%)	Sr (%)	Ca (%)	Ag (ppm)
14	56.3	704	2	<1	1.17	0.02	1
16	20.6	202	12	43.5	0.71	1.32	26.7
17	3.2	38	14	56.8	0.10	4.21	38.3
20	10.9	50	9	52.0	0.31	1.81	44.1
22	5.8	36	4	7.42	0.15	0.47	27.7

On the Bellevue Peninsula, numerous barite veins were discovered along a 1200 m length of the stream which flows northward into Tickle Cove (Figure 1). The veins pinch and swell from a few centimetres up to 1 m in thickness. They are steeply dipping and the strike varies from 0° to 025°. The host rocks are grayish black siltstones. The barite is pink and white, and quartz is sometimes present. Barite float is also widely scattered along the stream bed. All of these barite occurrences appear to be part of a northward trending system of subparallel veins, the most northerly expression of which is exposed along the south shore of Tickle Cove.

Seven barite veins ranging in width up to 30 cm were identified in two rock cuts on the railway line about 1 km east of Jacks Pond provincial park. The veins are vertically dipping and all trend in a northeast direction. The barite is pink in color and consists of coarsely bladed crystal aggregates. The host rocks are highly sheared and altered, northwest dipping sediments of the Connecting Point Group.

Cape Shore - St. Brides

A stream sediment survey was carried out in the St. Brides area of the southwestern Avalon. The sampled area includes several barite prospects, nearly all of which are exposed on the coast.

315 samples were collected from a 110 km^2 coastal strip between Cape St. Mary's and Angels Cove. Streams in this area generally flow in a westerly and southwestern direction across sedimentary formations which range in age from Hadrynian to Lower Cambrian. The samples were taken from active sediment at approximately 400 m intervals. Duplicate samples were collected routinely at every twentieth sample site to allow a quantitative assessment of sample variance to be estimated. The samples were dried and sieved to minus 80 mesh (<180 um) and are being analyzed for Ba, Sr, Cu, Pb, Zn, Ag, Fe, Mn and L.O.I..

Mineralization

Several minor occurrences of barite were noted during the stream survey. Barite float found in a tributary which flows southward into Cuslett Brook was traced to its source, which consists of poorly exposed veins, <10 cm wide, cutting red mudstone. Similar barite veining occurs in a road cut on Route #8 about 500 m west and along strike from the stream occurrence.

St. Lawrence Area

During the 1983 field season, a major rock sampling program was carried out on the known fluorspar veins in the St. Lawrence area. The main purpose was to assess the barite potential of vein deposits of fluorite-barite mineralization. Samples were also collected for use in a B.Sc. thesis study (being conducted at Memorial University of Newfoundland by C.J. Collins) on some aspects of the genesis of the ore deposits.

A total of 40 veins and showings were examined (Figure 2) resulting in the collection of more than 250 samples. Wherever possible, continuous sections were sampled across the entire width of the veins or as far as exposure would allow. Some veins and showings were sampled using grab samples of outcrop wherever possible. Some veins were not exposed at all, so there it was necessary to take grab samples of float or dump (trench or workings) material.

Conclusions

710 silt samples were collected from two project areas on the western Avalon Peninsula. In addition, more than 300 rock samples were collected from various veins and occurrences, including those in the St. Lawrence fluorspar district of the Burin Peninsula. Several new barite veins were discovered on the Avalon Peninsula, including a new barite-galena vein near Southern Harbour. Analyses of the stream sediment data will be released in 1984.

Acknowledgements

We gratefully acknowledge the competent assistance provided by Peter Bull and Karl Freake throughout the summer. Dr. Peter Davenport and Jim Butler were helpful on many occasions and their continuing help and interest are much appreciated. Wayne Ryder, Sidney Parsons, and David Warren cheerfully attended to our logistical needs. The help and encouragement of Paul Dean are also much appreciated.

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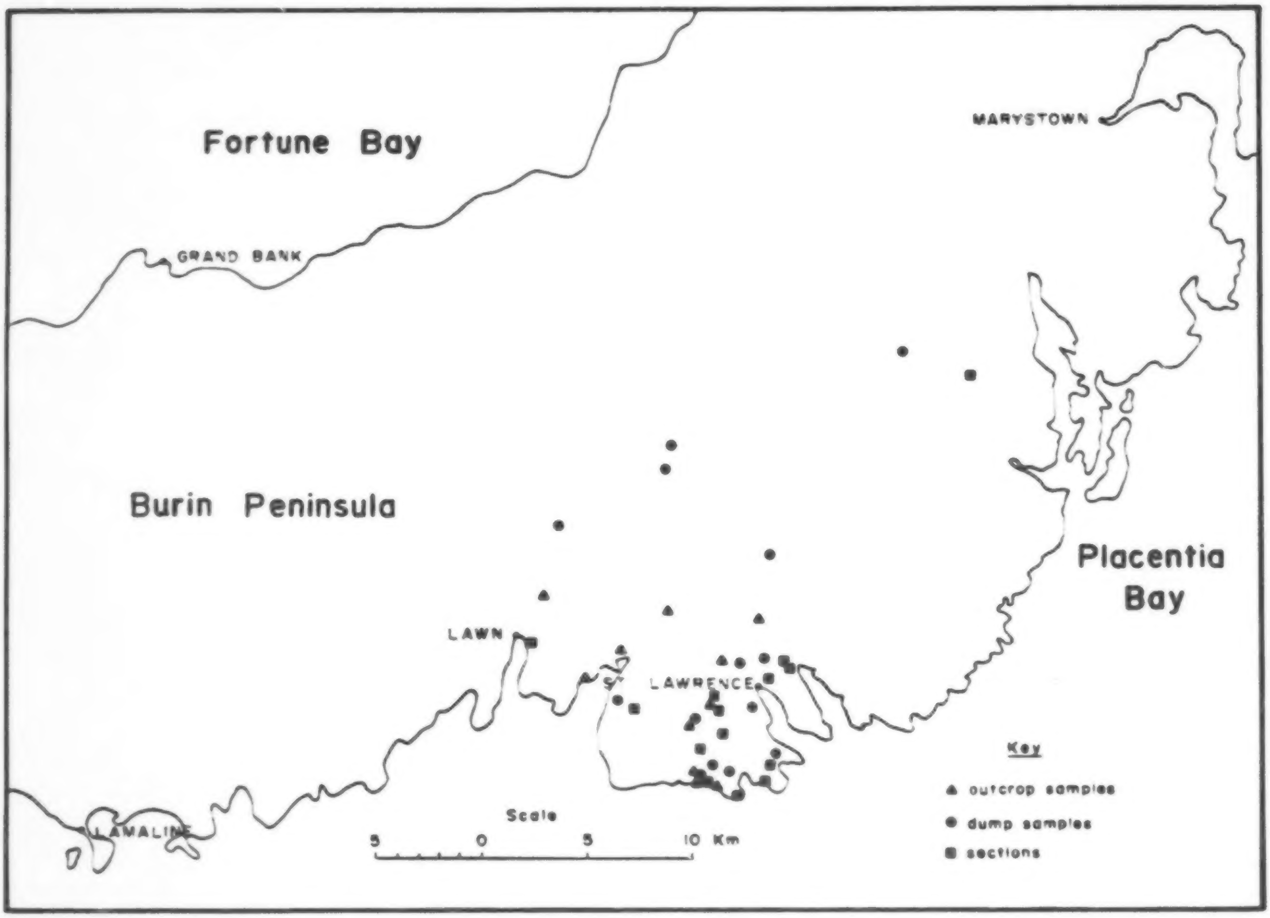
Fortune Bay
GRAND BANK
MARYSTOWN
Burin Peninsula
Placentia Bay
LAWN
ST. LAWRENCE
LAMALINE
Scale
5 0 5 10 Km
Key
▲ outcrop samples
● dump samples
■ sections

Figure 2: *Sample sites, St. Lawrence area.*

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A.F. House

GEOCHEMICAL FOLLOW-UP STUDIES IN EASTERN NEWFOUNDLAND

by

A.J. Butler and P.H. Davenport
Geochemistry Section

Introduction

Geochemical follow-up studies were conducted in three areas within the Avalon Zone in eastern Newfoundland (Figure 1) during the summer of 1983. These areas include: (A) a zinc anomaly near the town of Harbour Grace, an extension to the area studied by Dean and Meyer (1983); (B) a copper anomaly on the isthmus of Avalon, east of the village of Fair Haven, complementing a study by Howse *(this volume)* in the immediate area; and (C) a cobalt and minor lead anomaly in the Bonavista - Port Rexton area on the Bonavista Peninsula. In each of these areas, sediment samples were collected, generally at 300 m intervals along all streams, at stream junctions and on connecting streams between ponds. In the Fair Haven and Harbour Grace areas, water samples were also collected from the streams and the pH of the water was read on site using a pH paper of intermediate range (4 to 7) and in the laboratory using a pH meter. The stream sediment samples were analyzed for Cu, Pb, Zn, Co, Ni, Ag, Mn, Fe, Mo, F and L.O.I. (loss on ignition). The water samples were analyzed for Cu, Zn, Mn and Fe.

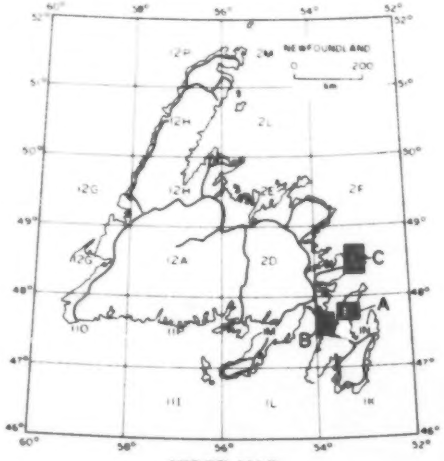


Figure 1: *Field study areas during 1983 season (A) Harbour Grace area; (B) Bellevue-Fair Haven area; and (C) Bonavista area.*

Harbour Grace Area

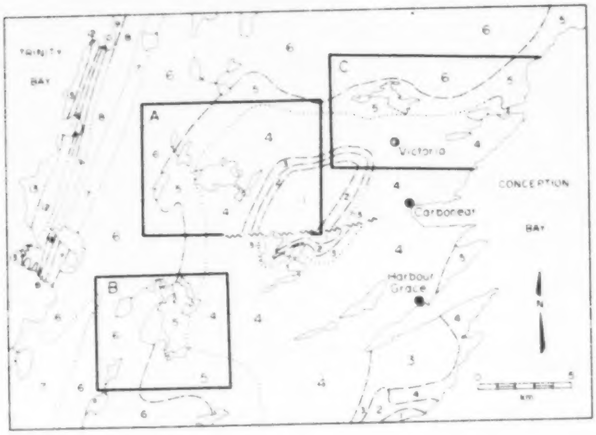
The regional zinc anomaly northwest of Harbour Grace (Butler and Davenport, 1979) can be divided into three areas for more detailed studies (Figure 2), namely, (A) the Saltpit Pond area which was investigated by Dean and Meyer (1983) and Meyer et al. (1983), (B) the Ocean Pond area, and (C) the Victoria area. The field work in 1983 was designed to extend the Saltpit Pond area (also assessed in 1983 by a private company) to the east (the Victoria area) and to the south (the Ocean Pond area).

Most of the area investigated is located along the contact between the massive, green, quartz-rich sandstone and siltstone of the late Precambrian Renews Formation and the thinly bedded, fine grained, black shale of the late Precambrian Fermeuse Formation which forms part of the St. John's Group (King, *in preparation)*. A detailed discussion of the geology of the area is presented by Dean and Meyer (1983) and Meyer et al. (1983).

The area is of low to moderate relief with forested and bog-covered areas near Ocean Pond and rocky barrens near Victoria. Both stream sediment and stream water samples were collected at most sites. Stream sediment sampling proved impossible at many sites due to poor stream development and the lack of sediment accumulation; at these sites, only water samples were taken. A total of 67 sediment samples and 85 water samples were collected.

The results of the water analyses were of little value. In most cases, neither Zn nor Cu was detected in the samples, whereas Mn and Fe were detected, but with no apparent trend.

Contribution to the Canada-Newfoundland co-operative minerals program 1982-84. Project funded by the Newfoundland Department of Mines and Energy and the Geological Survey of Canada.



LEGEND

MIDDLE CAMBRIAN	
13	*Chamberlains Brook and Manuels River Formations*
LOWER CAMBRIAN	
12	*Bonavista, Smith Point and Brigus Formations*
11	**Random Group**
PRECAMBRIAN	
10	*New Perlican Formation*
9	*Heart's Content Formation*
8	*Heart's Desire Formation*
7	*Quidi Vidi Formation*
Signal Hill Group	
6	*Gibbett Hill Formation*
St. John's Group	
5	*Renews Head Formation*
4	*Fermeuse Formation*
3	*Trepassey Formation*
Conception Group	
2	*Mistaken Point Formation*
1	*Drook Formation*

Figure 2: *Generalized geology map of Harbour Grace area showing areas of detailed work.*

The intermediate range pH paper was not sensitive enough to detect the very small changes in pH between samples and the results were not comparable to the pH values determined by pH meter at the department's laboratory.

The results of the stream sediment analyses will be compiled with those already published in Meyer et al. (1983) to provide more complete information on the Harbour Grace area. These data will be released in 1984.

Bellevue - Fair Haven Area

The main interest in the Bellevue - Fair Haven area was a lake sediment Cu anomaly outlined by a reconnaissance lake sediment geochemical survey of the western Avalon Peninsula (Davenport et al., 1975). The anomaly is located immediately east of the village of Fair Haven (Figure 3), and is underlain by mafic volcanic rocks of the late Precambrian Bull Arm Group (King, *in preparation).* As in the Harbour Grace area, 40 km to the east, this area is generally of low to moderate relief and covered with rocky barrens and forest, with poor stream development. A total of 145 stream sediment samples and 178 stream water samples were collected.

Here, as in the Harbour Grace area, the Zn and Cu concentrations in water samples were below the detection limit. The stream sediment sample analyses will be released in conjunction with the Mineral Deposits Section report on the same area (Howse, *this volume).*

Bonavista Area

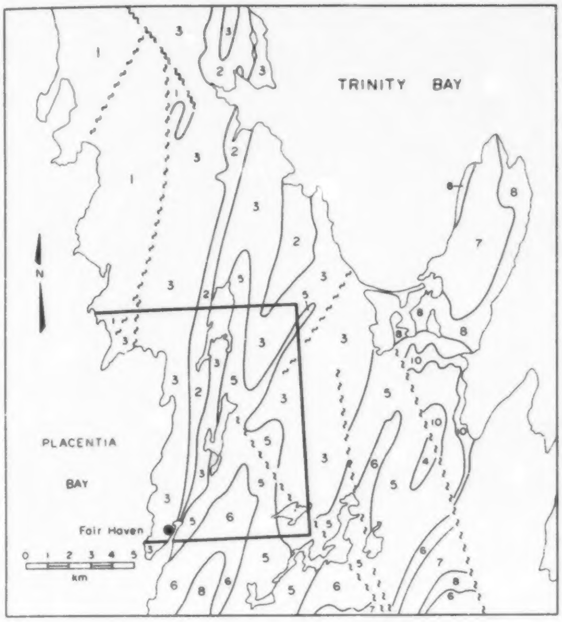
The Bonavista area (Figure 4) was included in the study because of a large multipoint Co anomaly and a less intense Pb anomaly indicated by a regional lake sediment geochemical survey (Butler and Davenport, 1981). The area was divided into two parts based on the distribution of the Co and Pb anomalies, Area A near Bonavista and Area B near Port Rexton (Figure 4).

The relief of the area is generally low and the area is covered with bog and, in places, dense forest. Stream development is relatively good. This area is underlain by sedimentary rocks of the late Precambrian Musgravetown Group, consisting mainly of red, green and gray conglomerate, sandstone and shale (Jenness, 1963).

A total of 460 stream sediment samples were collected from both areas. The analyses of these samples will be released in 1984.

Acknowledgements

We thank Dianne Andrews, Glen Bursey, Peter Carter, Margot Davis, Todd Dennis and John Elkins, the field crew, for their excellent effort during the field season and for their gallant attempts at gastro-



LEGEND

LOWER CAMBRIAN

11 *Bonavista, Smith Point and Brigus Formations*

10 **Random Group**

PRECAMBRIAN

9 *New Perlican Formation*
8 *Heart's Content Formation*
7 *Heart's Desire Formation*
6 *Quidi Vidi Formation*

Signal Hill Group

5 *Gibbett Hill Formation*

Bull Arm Group

4 *undivided*
3 *basaltic flows, etc.*
2 *silicic tuff, etc.*

1 **Connecting Point Group**

Figure 3: *Generalized geology map of Bellevue - Fair Haven area. Area of detailed work is outlined.*

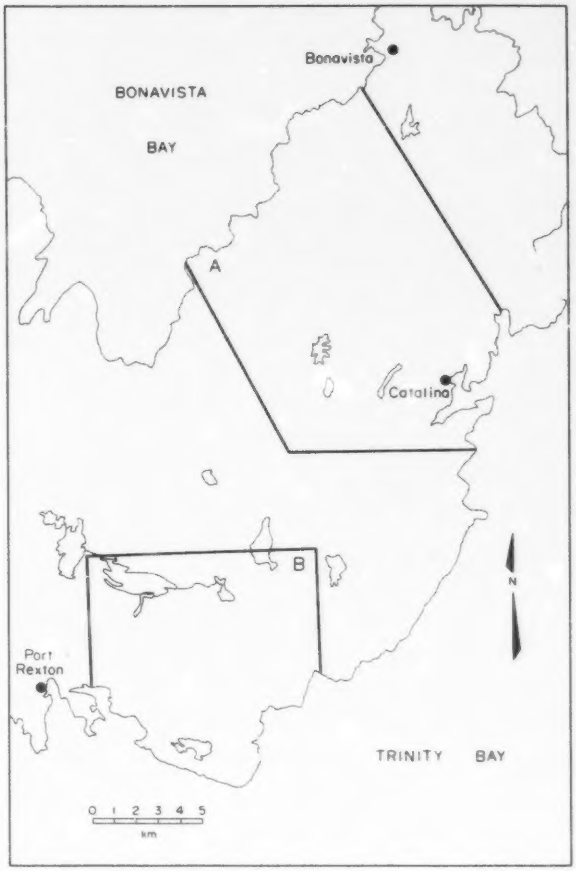


Figure 4: *Detailed area location map, Bonavista. Entire area is underlain by Musgravetown Group sedimentary rocks.*

nomic delights. Wayne Ryder, Sidney Parsons and Dave Warren assisted with the logistics of the field party.

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P.H. Davenport

GEOSCIENCE STUDIES IN THE WEIR'S POND AREA NORTHEAST OF GANDER, NEWFOUNDLAND

by

A.J. Butler, H.G. Miller[1] and D.G.Vanderveer
Geochemistry and Environmental Geology Sections

Introduction

During the 1983 field season, a geochemical anomaly in the Benton - Indian Bay Pond area (Figure 1) was investigated by geochemical stream sampling, a geophysical gravity survey and Quaternary mapping in order to locate its source. A regional lake sediment geochemistry survey (Butler and Davenport, 1981a,b) had indicated a major geochemical nickel (Ni) anomaly over the Gander River Ultramafic Belt (GRUB) and a less intense multipoint Ni anomaly approximately 20 km to the east near the village of Benton (Figure 2). This latter anomaly is underlain by Middle Ordovician Gander Group psammite, pelite and semipelite and by Square Pond Gneiss. Concentrations of the elements Zn, Co, Pb and to a minor extent Cu are associated with the less intense anomaly but not with the GRUB anomaly. This indicates that the source of the less intense anomaly probably differs from that of the GRUB anomaly, which is the ultramafic rocks of GRUB. A source for the anomaly in the Benton area is presently unknown, although mafic volcanic rocks in the Indian Bay Pond area (Blackwood, 1978) may be more extensive than initially thought.

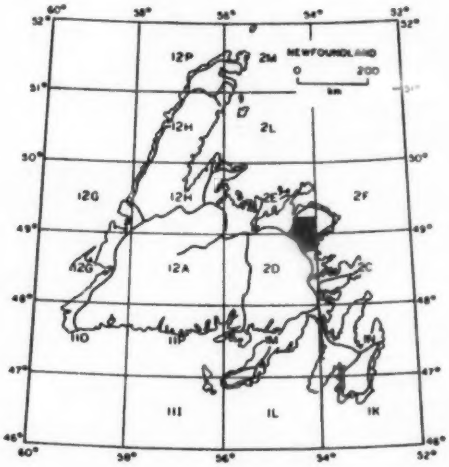

Figure 1: *Index Map.*

The area is of low to moderate relief and has fair to good stream development. It is heavily forested in some areas, particularly in the south, and has more open and rocky bog and barren areas to the north with fair to poor bedrock exposure.

Geochemistry

The area was divided into three parts (Figure 2) to facilitate field work, (A) the Soulis Pond area, (B) the Indian Bay Pond area, and (C) the Indian Bay Big Pond area. Each area was sampled independently, but the results of the analyses will be combined for public release.

In total, 239 stream sediment samples were collected at approximately 300 m intervals along all major streams and tributaries within the area. Analyses of these samples have been completed for Cu, Pb, Zn, Co, Ni, Ag, Mn, Fe, Cd, Mo and L.O.I. (loss on ignition) at Mines and Energy's laboratory in the Howley Building. Analysis for F is partially completed. The results are presently being computerized for statistical analysis.

Geophysics

Gravity data were collected using a LaCoste-Romberg land gravity meter, serial number G444. Elevations were obtained from barometric altimeters using survey methods to increase the accuracy of the results

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Contribution to the Canada-Newfoundland co-operative minerals program 1982-84. Project financed by Newfoundland Department of Mines and Energy, Geological Survey of Canada and Memorial University of Newfoundland.

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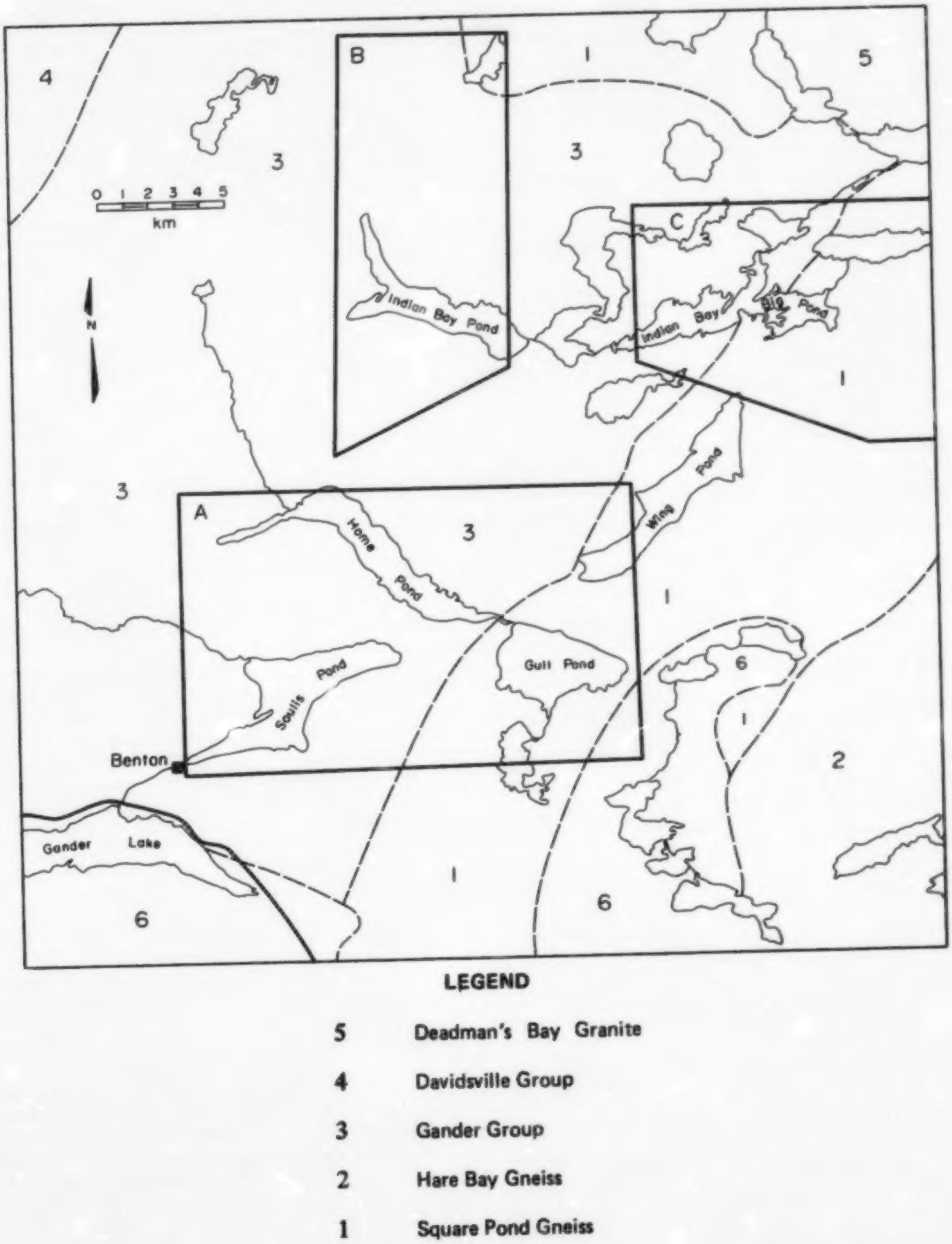

4
3
B
1
5
3
0 1 2 3 4 5
km
C
N
Indian Bay Pond
Indian Bay Big Pond
1
3
A
3
Home Pond
Wing Pond
1
Gull Pond
Soulis Pond
6
1
2
Benton
Gander Lake
1
6
6
LEGEND
5 Deadman's Bay Granite
4 Davidsville Group
3 Gander Group
2 Hare Bay Gneiss
1 Square Pond Gneiss

Figure 2: *Generalized geology of the Weir's Pond area, Northwest of Gander, Newfoundland. Detailed areas are (A) Soulis Pond; (B) Indian Bay Pond; (C) Indian Bay Big Pond.*

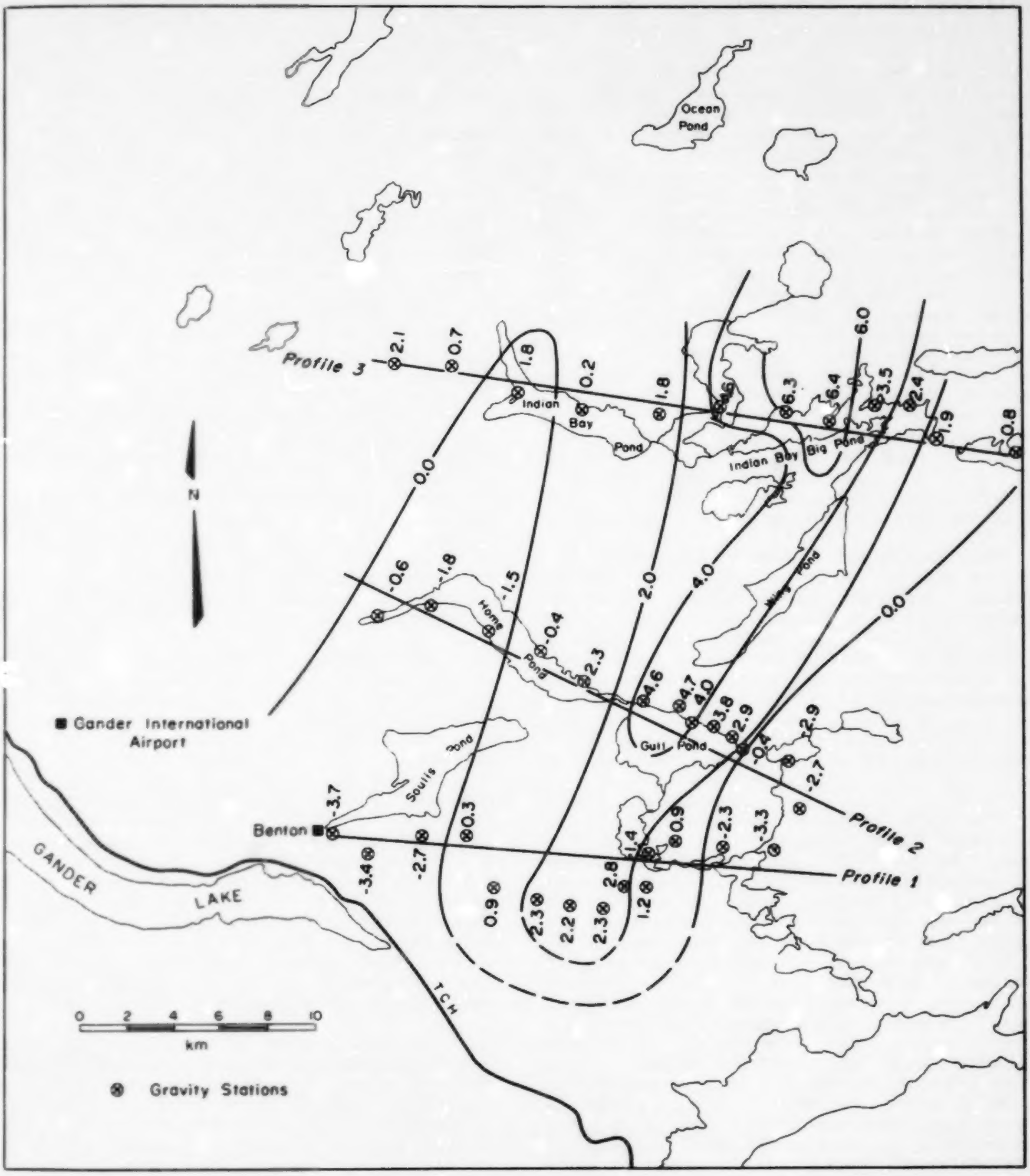

Ocean Pond
Profile 3
Indian Bay Pond
Indian Bay Big Pond
N
Home Pond
Gull Pond
Soulis Pond
Gander International Airport
Benton
GANDER LAKE
Profile 2
Profile 1
TCH
0 2 4 6 8 10
km
⊗ Gravity Stations
2.1
0.7
1.8
0.2
1.8
6.3
6.4
3.5
2.4
1.9
0.8
6.0
0.0
-0.6
-1.8
-1.5
-0.4
2.3
2.0
4.0
4.6
4.7
4.0
3.8
2.9
-0.4
-2.9
-2.7
0.0
-3.7
-3.4
-2.7
0.3
0.9
2.3
2.2
2.3
2.8
1.4
1.2
0.9
-2.3
-3.3

Figure 3: *Location of gravity profiles in Weir's Pond area. Station readings along profiles are in m. Gal.*

(Miller and Deutsch, 1976). Positions were plotted on 1:50,000 topographic maps. The gravity base at Gander is tied to the National Gravity Network which is the worldwide part of IGSN71 (Morelli et al., 1971). Bouguer anomalies at each station were calculated using the appropriate base value, the 1968 International Gravity Formula, and a crustal density of 2.67 $g.cm^{-3}$. These are absolute anomalies similar to those on the Canadian data base, and can be directly compared with other Bouguer anomalies calculated using this reduction system. In order to compare these anomalies with those on the older anomaly maps published for Newfoundland by the Dominion Observatory (Weaver 1967, 1968), approximately 6.3 mGal must be subtracted from the older data. Alternatively, the data collected by Weaver and revised by H.G. Miller (unpublished) on the new international datum may be obtained from the Earth Physics Branch, EMR, Ottawa.

The geophysical survey in the Benton area consisted of a total of 37 gravity stations arranged along three traverses (Figure 3). The traverses were designed to obtain more detailed geophysical information on the nature of the Ocean Pond anomaly, a belt of higher gravity and magnetic anomalies recognized by Miller and Weir (1982) to be coincident with a belt of geochemical anomalies similar to those found in the Gander River Ultramafic Belt to the west.

The data (Figure 4) demonstrate that the Ocean Pond anomaly consists of two parts, the western part termed the Ocean Pond anomaly, and an eastern part termed the Indian Bay Big Pond anomaly. The detailed gravity data of the present survey suggest that the Indian Bay Big Pond anomaly belt contains up to 1.5 km thickness of anomalous material at fairly shallow depth. The source dips westward and the anomaly broadens northward. Its northern extent cannot be interpreted from the available data. The largest anomaly found on the present survey was in the Indian Bay Big Pond area, suggesting an increase in peak anomaly northward. The Indian Bay Big Pond anomaly is consistent with reports of mafic volcanic rocks in the area (Blackwood, 1978) and with the geochemistry. Further interpretation involving modeling methods will be employed to determine the subsurface configuration of the anomalous material.

Quaternary Mapping

From a regional Quaternary perspective, the area lies within the "outer drift zone" described by Jenness (1960). No detailed field work had been conducted in the area prior to the present study, which was designed to provide an insight into the regional Quaternary sequences and the distribution of glacial drift throughout the area. Before 1983, the only systematic Quaternary assessment of the region was an interpretation of map areas 2E/8, 2F/4 and 2F/5 using aerial photographs and limited field investigations by the Environmental Geology Section (Vanderveer, 1977).

For the purposes of Quaternary mapping, the area is bounded by the Gander Bay road to the west, the Trans Canada Highway to the southwest, and the coastline to the east and north (Figure 5). Field work was concentrated on map areas 2E/1 and 2D/16 (north of the Trans Canada Highway), supplemented by some sampling on map areas 2D/9 and 2F/4. Prior to field work, a detailed Quaternary (landform) aerial photographic interpretation was carried out on parts of the study area not previously covered (viz. 2E/1 and 2D/16). Many of the decisions concerning sampling locations and sample densities were based on this interpretation.

The field program concentrated on providing sampling coverage as dense as possible, with the aims of defining the geochemical pattern in the tills, describing the distribution of drift across the area, and assessing the possibility of mineralized float or drift from the Gander River Ultramafic Belt being dispersed throughout the area. The field program consisted of (a) road surveys confined to the margin of the field area, where an adequate road system exists (there are few roads in the center of the region, on the 2E/1 map sheet); (b) 15 backhoe testpits to provide more detail on Quaternary stratigraphy; and (c) a helicopter-borne survey to reach inaccessible areas and to provide data on a systematic basis across 2E/1.

On the basis of the aerial photographic analysis, a grid spacing of 3000 m by 3000 m for sample sites was used where possible. At each site, profile sampling of at least the B soil horizon, B-C transition, and C horizon (parent till) was attempted for grain size and geochemical analyses. During the helicopter survey, the C horizon was rarely sampled due to either the bouldery nature of the upper surface or the wetness of the terrain. In the more northerly parts of 2E/1, frost boils were often sampled because of the bouldery nature of the drift. Pebble samples were also collected from the C horizon wherever possible for lithological analyses. In total, 369 samples were collected from 179 sites across the field area.

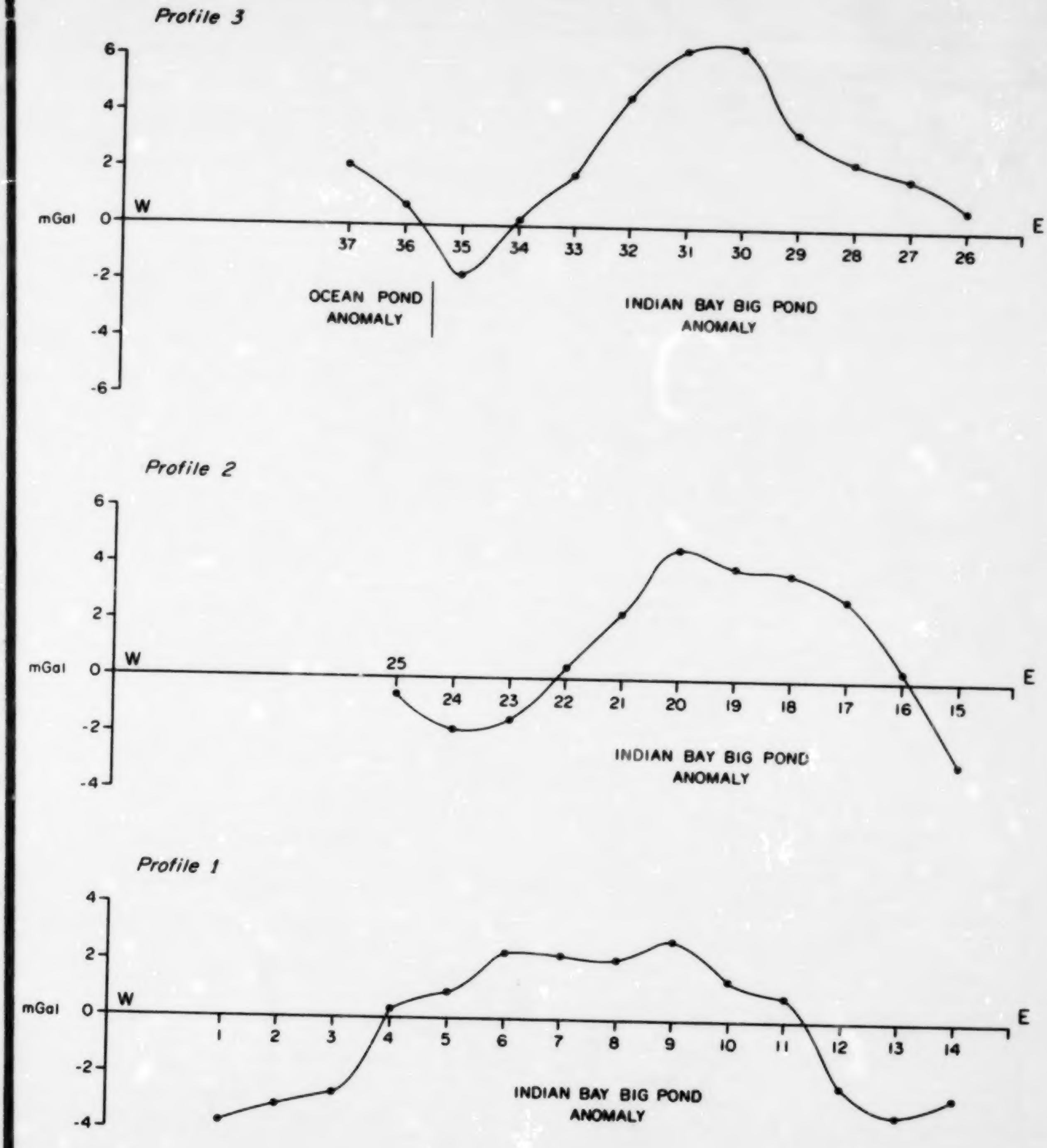
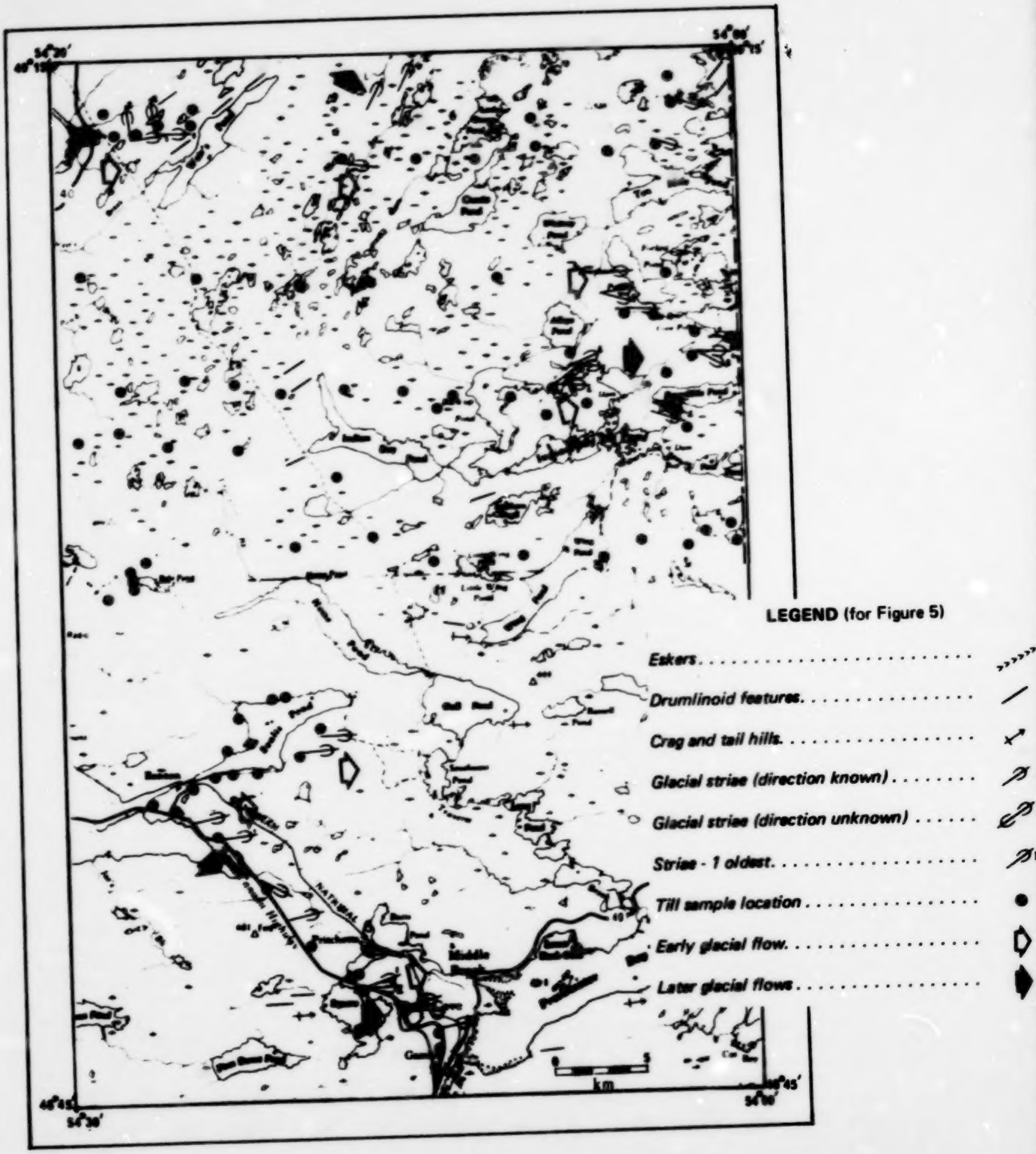


Figure 4: *Profiles from Weir's Pond area. Same scale as Figure 3.*


54°30'
49°15'
54°00'
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48°45'
54°30'
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54°00'
0
5
km
Middle Brook
NATIONAL
LEGEND (for Figure 5)
Eskers
Drumlinoid features
Crag and tail hills
Glacial striae (direction known)
Glacial striae (direction unknown)
Striae - 1 oldest
Till sample location
Early glacial flow
Later glacial flows

Figure 5: *Sample locations and ice flow directions in the North West Gander area (2E/1, 2D/16).*

Preliminary Observations

Glacial erosion suggests a dominant earlier flow towards the east (090° ± 15°), with a later overprint revealing a radial flow pattern that may be related to a remnant ice cap in the area as suggested by Grant (1974).

There is a lack of overburden towards the coast and in the northern half of the field area. The thickest deposits are those in the Butts Pond area and around Gambo; they are in part related to downwasting of the ice. The tills across the rest of the area may be described as gray to pink-gray in color, and sandy-silty in texture. Some are overconsolidated.

Some of the best stratigraphic sections in the study area are along the Trans Canada Highway (TCH). Between Butts Pond and Gambo Junction, multiple drift units have been identified. These consist of a gray sandy-silty till that overlies a pink, coarse sandy till(?) composed of clasts derived mainly from granitic terrains.

In a backhoe testpit midway between Butts Pond and Gambo Junction, a sequence was exposed of sandy to silty, gray-brown till over rhythmites of fine sand, silt and clay over a gray compact fissile till.

Northwest of the TCH - Gambo junction, a roadcut of approximately 30 m plus a backhoe testpit at the base of the section revealed a mantle (1 to 3 m) of glaciofluvial gravels overlying an alternating sequence (20 to 25 m thick) of sandy, silty gray till and pink sandy till that in turn overlies stratified sands and gravels that extended to depth beyond the reach of the backhoe (i.e. 4 m below the level of the TCH). Just north of the TCH - Gambo Junction, a sequence of sandy tills overlies sand-silt lenses and rhythmites which may be of marine or glaciomarine origin.

The elevation of the presumed marine sediments (rhythmites) indicates that sea level has fallen approximately 30 m since deglaciation. These sequences represent complex marginal/submarginal deposition. Unfortunately, data are not available to permit correlation between depositional units, and therefore an accurate interpretation of the glacial history cannot be presented at this time.

South of Big Bear Cove Pond, hand size fragments of mineralized float containing chalcopyrite in argillite and pyrite in a graphitic pelite were found at Military Grid Reference 179435 in map area 2E/1.

Analysis of the collected samples for grain size distribution, geochemistry (Cu, Pb, Zn, Co, Ni, Ag, Mn, Fe, Cd and Mo) and lithologies is ongoing. Supplementary data are also currently being investigated.

Data Release

Analysis of samples collected during the geochemical and Quaternary studies is nearing completion. More detailed geophysical modeling is being done using an expanded data base of previously collected data. After this has been completed, all the data will be compiled and released as an open file.

Acknowledgements

The geochemical crew of Dianne Andrews, Peter Carter, Margot Davis, Todd Dennis and John Elkins is thanked for excellent work while sampling this area. Margot also assisted in the collection of the geophysical data. Bill Turner and Baxter Slade of Universal Helicopters (Nfld.) Ltd., Gander, were most cooperative during the geophysical survey, the geochemical survey and flycamp moves. Jeff Steiner and Paul Skeard are thanked for their assistance on the Quaternary survey, and Martin Batterson for his continued assistance in preparing the photographic interpretations and in the field survey on the Quaternary component.

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A NEW PROVISIONAL GEOLOGICAL MAP OF THE ISLAND OF NEWFOUNDLAND

by

James Hibbard[1]
Mineral Deposits Section

Introduction

Since Jukes first undertook a geological survey of Newfoundland in 1839, the major objective of the Newfoundland Department of Mines and Energy has remained ".... to know what are the different earthy or mineral masses of which the country is composed, and what are their relative and actual positions" (Jukes, 1842a). A new 1:500,000 scale geological map of the island of Newfoundland, compiled during the first half of 1983, represents the most recent stage in the fulfillment of this objective.

The new map was compiled mainly to serve as a base map for a forthcoming metallogenic map of the island. However, it has been printed in color at 1:1,000,000 scale and placed on open file to serve as a provisional new geological map of the island (Hibbard, 1983). The long range prospect for the map includes revision by the Newfoundland Mapping Section over the next few years and, hopefully, publication at 1:500,000 scale.

More than fifteen years of intensive geological mapping have been undertaken since the last map of the island of Newfoundland was produced. Most of the new mapping has been done by government surveys. During the 1960's and early 1970's, the task was largely the responsibility of the Geological Survey of Canada, but since the mid-1970's, a revitalized Newfoundland Department of Mines and Energy has developed an extensive 1:50,000 scale mapping program on the island. This mapping has largely been the result of agreements jointly funded by the governments of Newfoundland and Canada, and some of it has been done jointly with the Geological Survey of Canada. In addition, the results of work by industry and academia have been used in the compilation of the new map. Government-financed mapping of the island is continuing, so this new map will be progressively updated.

History

The new map is heir to a succession of geological maps of the island that date back to 1842 (Jukes, 1842b). Baird (1954a) summarized more than one hundred years of development of Newfoundland mapping when he published a geological map of the island (Baird, 1954b); his review included short discussions of a geological map of the island by Howley (circa 1905), a sketch map of the island by Snelgrove (1937), and an unpublished map by E.R. Rose (circa 1947), as well as a description of his own map. The present map is a direct descendant of Williams' 1967 map, which succeeded Baird's contribution.

The New Map

This new map of Newfoundland partly reflects its predecessors, yet has features that give it a distinctive character. Its close relationship to Williams' 1967 map is most apparent in the overall layout of the legend. The legends of both are divided into three major parts, including western, central and eastern Newfoundland. These divisions are based mainly on geography; however, they also reflect, roughly, the major Ordovician and older lithostratigraphic divisions of the island as first presented by Williams (1964, 1967). The three divisions are linked by mere lithostratigraphic shreds; the western and central areas share anorthosite bodies (along the Cabot Fault) and ophiolitic suites of similar ages, whereas the central and eastern areas are linked by Devonian granite. Carboniferous rocks overlap both the western and central areas and occur in small patches in the eastern area.

The distinctive character of the new map is evident in the division of rock units within each area. The philosophy of the new legend is based on distinguishing major depositional and intrusive packages through time for each of the three parts of the island. This compilation scheme contrasts with that of the 1967 version, which was based on a 'lumping solely by age' style of legend. The new refinement is possible mainly because of the finer scale of geological maps now available. The finer scale maps have also allowed for major changes in the boundaries between units, especially in southern and central Newfoundland. Stratigraphic nomenclature plays a minor role on the new map, and is keyed to numerical subscripts. For example in the central area, a major depositional package of mainly basinal clastic rocks includes the Davidsville, Baie d'Espoir, and Bay du Nord Groups; the package is labelled **Ocs** for Ordovician clastic sedimentary rocks, and the individual groups listed are given numerical subscripts 1, 2 and 3, respectively.

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The following is a summary of the legend. The divisions discussed below have been distilled from the work of numerous geologists; for the sake of brevity, references are not included.

Western Newfoundland

The legend for the western part of Newfoundland reflects the well established tectonic history of the area; its divisions record the evolution and destruction of an Early Paleozoic continental margin. The major stratified rock packages (including ophiolites) include the following:

(1) a Precambrian infrastructure of mainly undivided gneisses;

(2) an Eocambrian-Cambrian mixed siliciclastic and carbonate sequence that overlies (1), and is in part related to the rift formation of the continental margin;

(3) three divisions of a Cambro-Ordovician carbonate bank (based on age and depositional environment) that were deposited on (2);

(4) a Middle Ordovician flysch sequence that covers part of (3);

(5) allochthonous Cambro-Ordovician sedimentary, volcanic, ophiolitic igneous and metamorphic rocks that were derived from an area at the eastern edge of the continental margin;

(6) Middle Ordovician parallochthonous sedimentary rocks that were deposited upon the allochthonous rocks as the latter were emplaced;

(7) Ordovician to Silurian neoautochthonous sedimentary rocks deposited upon the emplaced allochthons; to the east, these include felsic volcanic rocks;

(8) deformed and metamorphosed Lower Paleozoic rocks equivalent to those listed above;

(9) Devonian to Carboniferous fluviatile, lacustrine and shallow marine sedimentary rocks.

The major plutonic divisions in the western area include the following:

(1) a variety of Precambrian intrusions in the crystalline infrastructure;

(2) a Precambrian to Cambrian diabase dike swarm that intrudes the crystalline infrastructure and lower parts of the mixed siliciclastic and carbonate sequence;

(3) Silurian to Devonian granitoid rocks along the eastern margin of the area.

Central Newfoundland

As for the western area, the legend for central Newfoundland reflects an established tectonic history; the divisions document the evolution of a Lower Paleozoic volcanic arc system and associated sedimentary basins that were apparently in large part initiated on oceanic crust. The major stratified units (including ophiolites) include the following:

(1) a Cambrian(?)-Ordovician ophiolitic basement equivalent to allochthonous ophiolites of western Newfoundland;

(2) paragneisses that may be related to Precambrian rocks of the western part of the island;

(3) Lower Ordovician "early" volcanic arc sequence with associated sedimentary rocks;

(4) a southeastern basinal clastic facies that appears to be in part coeval with the "early" arc;

(5) a distinct Middle Ordovician black shale and siliceous argillite unit;

(6) an Upper Ordovician to Devonian "late" volcanic arc sequence with associated sedimentary rocks;

(7) a sequence of apparently Ordovician quartz-rich clastic rocks that may have been derived from either more silicic parts of the "early" arc or an undiscovered continental source;

(8) undivided, mainly metamorphic rocks that may, in large part, be equivalent to facies listed above;

(9) Devonian to Carboniferous volcanic rocks and fluviatile to lacustrine sedimentary rocks.

The plutonic divisions used for the central area of the new map are not fully established, but relate in part to the volcanic arc but probably more to syn- and post-arc tectonics. The following divisions are tentative, because diagnostic data used in separating intrusions are generally of an analytical nature, such as radiometric dates, petrochemistry, and isotopic ratios, and because work has been carried out only on a cursory regional scale. The plutonic divisions are as follows:

(1) Precambrian anorthosite and possible Precambrian granitoid rocks, probably related to similar age rocks of western Newfoundland;

(2) Ordovician granitoid rocks, including extensive areas of tonalitic to granodioritic rocks;

(3) Ordovician to Silurian granitoids and minor related mafic phases;

(4) a variety of divisions of Ordovician to Carboniferous granitoids and mafic intrusions that are separated on the basis of mineralogy, petrochemistry, physical features, and age constraints (mainly radiometric);

(5) Jurassic, mainly mafic stocks.

Eastern Newfoundland

The eastern Newfoundland legend is composed of well established depositional and plutonic packages; however, the unified tectonic theme of the belt is not totally clear. In recent years, the rocks of the area have been considered to represent an episode of Early Hadrynian rifting with subsequent abortion, foundering and infilling of the rift basin. The major stratified divisions of the new map include the following:

(1) Early to Middle Hadrynian mafic volcanic rocks and associated sedimentary rocks;

(2) Hadrynian basinal sedimentary sequences, one of which includes a distinctive mixtite unit;

(3) Late Hadrynian bimodal volcanic sequences;

(4) Late Hadrynian shallow marine to fluviatile sequences;

(5) Eocambrian to Lower Ordovician shallow marine clastic and carbonate rocks;

(6) Devonian to Carboniferous alluvial, fluvial, and lacustrine clastic rocks and mainly felsic, subaerial volcanic rocks.

Outstanding Problems

This new provisional map reflects the major tripartite division of the island; however, several previously unrecognized second-order patterns of undetermined significance can also be recognized. Three such patterns may be particularly significant and are discussed below.

(1) Tonalitic to granodioritic gneisses and migmatites of apparently pre-Devonian age cradle the central area on three sides. These units include the informal Southwest Brook Complex and southwesterly equivalents, the Cinq Cerf Complex, tonalitic migmatite at Grey River, tonalitic rocks of the Little Passage gneisses and the Hare Bay Gneiss. It is uncertain whether these compositionally similar units are related to distinct pre-Devonian magmatic events or to a single progressive event that affected all of the central belt. Resolution of this problem would help to show if the central belt was a mosaic of 'terranes' or a unified arc system prior to the Devonian.

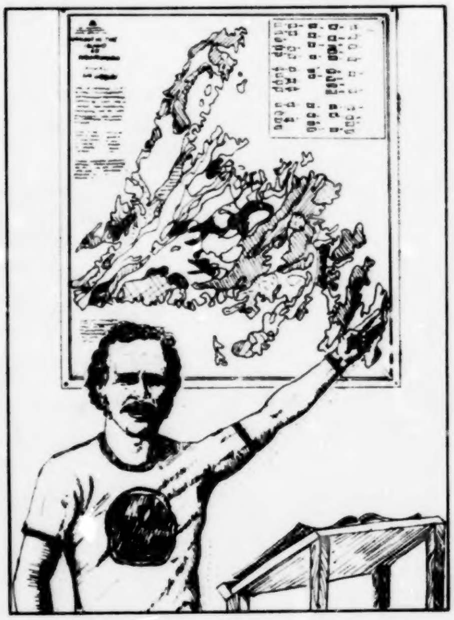
(2) Quartz-rich clastic rocks occur along strike from each other all along the Hermitage Flexure. These rocks appear to be Ordovician in age, but have been interpreted to have had different sources. Some siliciclastics appear related to the felsic volcanic-rich La Poile Group, whereas others, such as the Gander Group, have been traditionally interpreted to be of continental derivation. Still others, such as the informal Spruce Brook group, appear to have been overthrust by ophiolites of the central belt and are of uncertain origin. Further work on all these units should determine their origin, whether they are related, and the nature of the eastern side of the central belt.

(3) The Baie Verte Flexure has been interpreted as representing the original morphology of the ancient North American continent. Eocambrian dikes related to rifting and the formation of Iapetus Ocean trend southward, through Grenville gneisses of the northern Long Range Mountains, as far as the latitude of the flexure, where they appear to deflect westward. At the same latitude and slightly to the west, the northward striking Cow Head carbonate breccias abruptly terminate. It has been suggested recently that the Cow Head rocks may be autochthonous, rather than allochthonous as previously thought (R.K. Stevens and S. Stouge, personal communications, 1983), on the basis of the state of preservation of conodonts. The problem is to determine whether or not these features are related to the morphology of the ancient margin, and whether rocks formerly interpreted as allochthonous are actually autochthonous.

Closing Remark

My feelings about this map are best expressed in a quotation with which Baird (1954a) also ended his report on the 1954 geological map:

> "With regard to the distribution of the geological formations, it will be clear to anyone at all conversant with the difficulties attendant upon drawing in boundary lines with accuracy, especially in wild unknown or unfrequented regions, that many alterations and modifications will hereafter be necessary before the map can be considered by any means complete; nevertheless, I feel tolerably sure that the approximation is such as to be of considerable service for present purposes, and will be a useful guide for future and more minute investigation of details."
>
> Alexander Murray (1881)



.... and here, on the last leg of our field trip, we will come to taverns 131 - 198 located just east of the prodelta and frontal delta deposits of the St. John's Group.

Acknowledgements

I appreciate the efforts of all those who contributed information during compilation of the map; you are all listed on the map. I thank Paul Dean and Hank Williams for review and constructive criticism of the legend, Ken Byrne for procuring the base map and his continued help with map reduction, and Jane Murray for editing the legend. I am grateful to S.P. Colman-Sadd, I. Knight, R.V. Gibbons, J. Murray and S. O'Brien for comments that helped to improve this manuscript.

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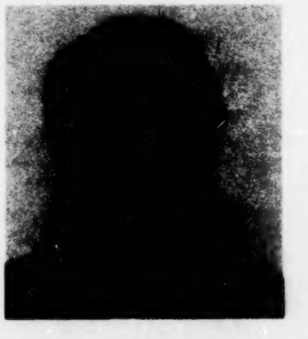

James Hibbard

MINERAL POTENTIAL OF CLASTIC SEDIMENTARY BASINS IN NEWFOUNDLAND

by

P.L. Dean and J.R. Meyer
Mineral Deposits Section

Introduction

A continued evaluation of the mineral potential of clastic sedimentary basins in Newfoundland was conducted during the summer of 1983 (Figure 1). Four open file reports on the work carried out in the previous two summers were released in July, 1983. The first three were "Stream Sediment Geochemistry of Three Sedimentary Sequences in Insular Newfoundland", Open Files 1K (19), 1N (440) and NFLD. (1316). The fourth was "Lithogeochemistry of Middle Ordovician Chert and Shale of Central Newfoundland", Open File Nfld. (1317). During the 1983 field season, follow-up work was carried out in the Avalon South (1K (19)) and Humber Arm North (Nfld. (1316)) areas. Mineralization coincident with the indicated anomalies was discovered in the former. Follow-up of the Middle Ordovician chert and shale study discovered visible base metal sulfides coincident with several base metal/barium anomalies, and fluorapatite nodules coincident with a phosphate anomaly. More detailed work on rock samples collected may identify the mineral phase containing the barium, which is present in amounts up to 2%. The shale lithogeochemistry program was expanded to cover the potassium-rich Cambrian "Forteau Shales" on the Great Northern Peninsula, and the Cambro-Ordovician shales of Random Island and adjacent areas. Follow up of lake sediment base metal anomalies on the western side of the Baie Verte Peninsula yielded several new mineral showings all of which coincided extremely well with the geochemical anomalies.

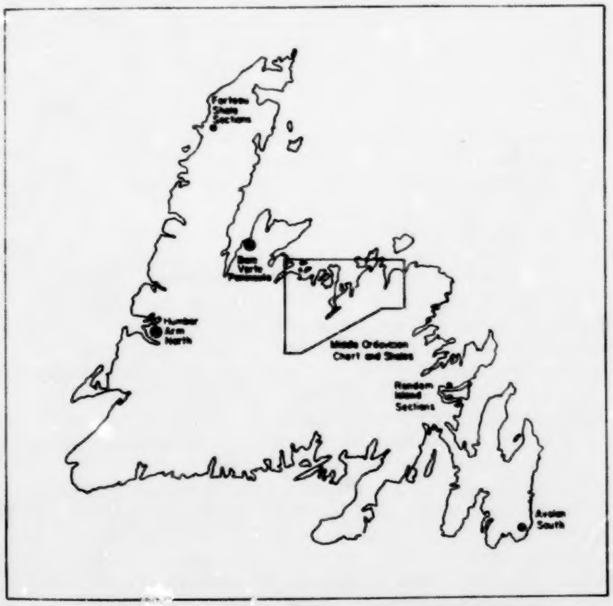

Fig.1 Mineral Potential of Clastic Sedimentary Basins in Insular Newfoundland - 1983 Field Areas

Open File Reports

Four open file reports were released in July, 1983. Results from the 1982 stream sediment geochemistry program (Dean and Meyer, 1983) constituted three releases, two from the Avalon Peninsula (Avalon South - 1K (19) and Avalon North - 1N (440)) and one from western Newfoundland (Humber Arm North - Nfld. (1316)), east of the Bay of Islands. Analyses released for each area include either 8 or 9 single element maps (Zn, Pb, Ni, Cu, Co, Cd, Fe, Mn, ± Ag and F), a loss-on-ignition map, either 4 or 5 residual maps (single element regressions with Fe, Mn, and/or L.O.I.), and sample location maps. Brief reports outlining the geology of the areas and the methods of analysis accompany each report. The Avalon North area was actively explored during the 1983 field season by private industry.

The fourth open file report (Nfld. (1317)) contains results from a lithogeochemical study of Middle Ordovician chert and shale from central Newfoundland (Dean and Meyer, 1982). Twenty-four sections were mapped and sampled in detail and 995 samples were analyzed for 24 major and minor elements. The analytical results, accompanied by statistical analyses and field data, are contained in a computer printout. Detailed stratigraphic sections and location maps are included for each sampled area.

Contribution to the Canada-Newfoundland co-operative minerals program 1982-84. Project funded by the Newfoundland Department of Mines and Energy and the Geological Survey of Canada.

Avalon South

The results of the 1982 stream sampling (Dean and Meyer, 1983) confirmed the presence of Zn-Pb-Co lake sediment anomalies (Davenport et al., 1975; Butler and Davenport, 1979) in the Chance Cove and Portugal Cove Brook areas. Coincident Cu, Cd and Ni anomalies are also present. Concentrated prospecting of the bedrock and *in situ* float discovered visible sulfide mineralization near several of the anomalies. The style of mineralization is similar to that in the northern Avalon Peninsula, west of Carbonear (Dean and Meyer, 1983). Chalcopyrite, sphalerite and galena were found as isolated blebs in medium to coarse grained sandstone of the Hadrynian Drook Formation, often associated with 1 to 5 mm black weathered pyrrhotite blebs. Oval pyrrhotite-magnetite "eyes" (2 to 5 mm in length) were observed in fine grained siltstone, and may contain minor base metals. New lithologic observations within the Drook Formation include boulders of volcano-sedimentary breccias and tuffaceous rocks which form a rough northeast trend 2 km northwest of Route 10. A Ag-Pb-Ni-Cu anomaly occurs in the vicinity of the tuffaceous rocks.

Humber Arm North

The stream sediment analyses from this area (Open File Nfld. (1316)) show localized base metal anomalies with few real trends and no noticeable groupings or combinations of elements. However, in the vicinity of Pynn's Pond, stream sediment Pb anomalies corresponds to lake sediment Pb anomalies reported by Butler and Davenport (1980). A slight correspondence of Cu anomalies and red slates and shales of the Upper Summerside Formation was noted. Mineralization found during follow-up work in 1983 included thin laminations of pyrite hosted by black shales of the Irishtown Formation, and minor malachite in sandstone of the Summerside Formation.

Middle Ordovician Chert and Shale of Central Newfoundland

Geochemical analyses of Middle Ordovician chert and shale sections sampled in 1981 indicate base metal and other anomalies (i.e. Ba, P, Mn, etc.) (Dean and Meyer, 1981). As a result, a short follow-up program was carried out in 1983. Galena was observed in 1 to 2 cm thick Mn-carbonate bands and along fracture planes in the lower intervals of the Luscombe Point section at Loon Bay. Isolated blebs of chalcopyrite were observed in the Loon Bay road section, site of the most impressive Ba, Pb, Zn, Cu, Ni and Ag anomalies. Barium is present in amounts up to 2%; however, the mineral(s) containing the barium have not yet been identified. The Loon Bay road section has total iron concentrations of up to 20% in several intervals which display massive, well banded pyrrhotite and pyrite mineralization.

Dense black nodules sampled from the black chert and shale at Lawrence Harbour South contain 26% P_2O_5, 34% CaO, 25% SiO_2, and 22,110 g/t fluorine. These are thought to be fluorapatite nodules. They contain very thin (<1 mm) quartz veins, and vary in shape and size from small rounded nodules 3 cm by 5 cm to large elongate lenses 15 cm by 40 cm. (The latter have not yet been analyzed.) The nodules occur in six intervals at the Lawrence Harbour South section, and three intervals at the Red Cliff section.

Northern Peninsula

Reconnaissance sampling of the Cambrian "Forteau shales" on the Northern Peninsula indicate a high K_2O content (R. Stevens, personal communications, 1977 and 1983). These shales are readily exposed in quarries along the western portion of the Roddickton road (Route 432) and immediately to the south at Three Mile Pond. Four relatively undeformed sections were sampled in 3 m intervals. The shales are dark gray, weather rusty brown; and are medium to thickly laminated and very friable. They are generally very calcareous, rarely manganiferous and contain trilobite imprints, pyrite nodules and beds rich in limestone nodules. A fine to coarse grained clastic limestone unit usually overlies these shales.

Random Island

Two representative sections of Cambro-Ordovician shale (and slate), sandstone and limestone were sampled in the Random Island area on the west side of Trinity Bay. A 2.5 km coastal exposure at Smith Point contains an excellent section of the Lower to Middle Cambrian Adeytown Group, which disconformably overlies the Random Formation near White Rock (Jenness, 1963). It consists of dominantly green to brownish red slaty shale with limestone concretions, and interbedded thin to thick, pink, green and gray limestone beds, some of which exhibit very resistant algal structures. There are several thin silty horizons, a 6 m thickly bedded sandstone interval, and a single 1 m thick, extremely dense manganiferous zone. Dark gray and black shale at the base of the conformably overlying Harcourt Group was sampled at the top of this section in Broad Cove.

A more complete section of the Harcourt Group was sampled on the south side of Random Island, between Fosters Point and Elliotts Cove. The change from red and green to gray and black shales approximately 0.75 km north of Fosters Point marks the base of the Harcourt Group. The southern half of the section consists of steeply dipping, undeformed, gray to black shale and slaty shale with minor siltstone, sandstone and limestone. The shale typically weathers rusty brown, appears sulfur-rich, is very friable and contains calcareous concretions 5 to 30 cm in diameter. Two porphyritic dikes 10 and 50 cm thick were observed and contain minor pyrite. The northern half of the section consists of strongly deformed black and gray graphitic shale with thin sandstone interbeds and calcareous concretions. Each of the lithologies mentioned above was sampled in at least one location. Additional samples of the Harcourt Group were collected trom the shale quarries operated by Trinity Brick Ltd. at the northwest end of Random Island.

Baie Verte Peninsula

Base metal anomalies are indicated by lake sediment geochemistry (Butler and Davenport, 1980) on the western side of the Baie Verte Peninsula (Figure 2). A northern trending series of copper anomalies which parallel represent lithologic trends are present in the Westport area, and localized Zn-Cu and Zn-Pb anomalies occur between Baie Verte and Seal Cove. The region is underlain by highly metamorphosed rocks of the Eocambrian to Middle Ordovician White Bay and Old House Cove Groups. These rocks consist mainly of northeasterly striking psammite and pelite with lesser marble, mafic and graphitic schist and amphibolite. The psammite in the Westport area contains very minor pyrite; however, 12 km to the northeast, on the west side of East Pond, quartzose bands in a garnetiferous psammite contain chalcopyrite and pyrite mineralization. A coincident Cu-Ag high in the lake sediment geochemistry was noted. Graphitic schists exposed in roadcuts halfway between Westport and Western Arm contain up to 4% pyrite-pyrrhotite mineralization. The 'amphibolite' units, interpreted as dikes, sills and flows, intrude and are part of the Old House Cove Group and older rocks in the area. They are dark green, usually porphyroblastic, and frequently host chalcopyrite mineralization (2% in grab samples). These units occur adjacent to ponds with anomalously high copper values in their lake sediments. Vuggy boulders of 'amphibolite' contain veinlets of ruby red, glassy to resinous sphalerite(?) and disseminated chalcopyrite in the Osbournes Pond area. The veinlets are 1 to 10 mm thick, up to 10 cm long, and often intimately associated with calcite and quartz veins. Other 'amphibolite' boulders found on the shores of this pond contain up to 1 to 2% combined chalcopyrite-pyrrhotite. A road quarry 2 km west of Osbournes Pond contains quartz-carbonate veins which host galena, sphalerite(?), molybdenite and pyrite mineralization. Rusty weathering pelites 1.5 km east of the same pond contain up to 5% chalcopyrite-pyrrhotite-pyrite mineralization. All the mineralization found in this area coincides remarkably well with the lake sediment geochemistry.

Conclusion

The evaluation of clastic sedimentary basins in Newfoundland has been largely based on a geochemical approach. Lake sediment geochemistry has identified base metal anomalies in at least four areas which are underlain by sedimentary rocks. One of the areas was explored by private industry in 1983, while our prospecting and stream sampling in two of the other areas confirmed the original anomalies and found many new mineral showings in bedrock.

The lithogeochemical study of central Newfoundland chert and shale has confirmed the existence of metal-rich, fine grained sedimentary rocks. Variations in the concentration of elements, such as Ba, by amounts of 200 to 20,000 g/t suggest introduction, migration and/or concentration by

LEGEND (Figure 2)

MIDDLE ORDOVICIAN TO HADRYNIAN

RATTLING BROOK GROUP (Unit 9)

9 *Unseparated semipelitic, pelitic and psammitic schist; minor greenschist, marble and graphitic schist.*

WHITE BAY GROUP (Units 5-8)

8 *Unseparated semipelitic, pelitic, and graphitic schist with subordinate psammitic, garnet porphyroblastic, and mafic schist; minor marble and quartz pebble metaconglomerate.*

7 **PIGEON ISLAND FORMATION:** *Mainly garnet porphyroblastic quartz-muscovite semipelitic schist, feldspathic psammitic schist, locally magnetite-rich, and graphitic schist.*

6 **GARDEN COVE FORMATION:** *Medium to dark green amphibolite and mafic schist, locally fragmental.*

5 *Mainly marble and carbonate schist, local marble breccia and conglomerate; minor quartzite.*

OLD HOUSE COVE GROUP (Units 3 and 4)

4 *Buff to gray weathering, medium to coarse grained psammitic and semipelitic schist , minor pebbly psammitic schist and graphitic schist.*

3 *Medium to coarse grained feldspar porphyroblastic mica schist, tectonically derived from Units 1 and 4.*

HADRYNIAN AND EARLIER (?)

EAST POND METAMORPHIC SUITE (Units 1 and 2)

2 **MIDDLE ARM METACONGLOMERATE:** *Mainly polymictic metaconglomerate with interlayered buff to gray psammitic schist.*

1 *Dominantly fine to medium grained gray psammitic and semipelitic schist and gneiss, may include rocks equivalent to Unit 4; 1a, migmatite gneiss and gray banded quartzofeldspathic gneiss, minor pink granitic gneiss.*

/ *Mainly massive, blackish green amphibolite dikes, sills, and pods; locally eclogitic in Units 1 and 2.*

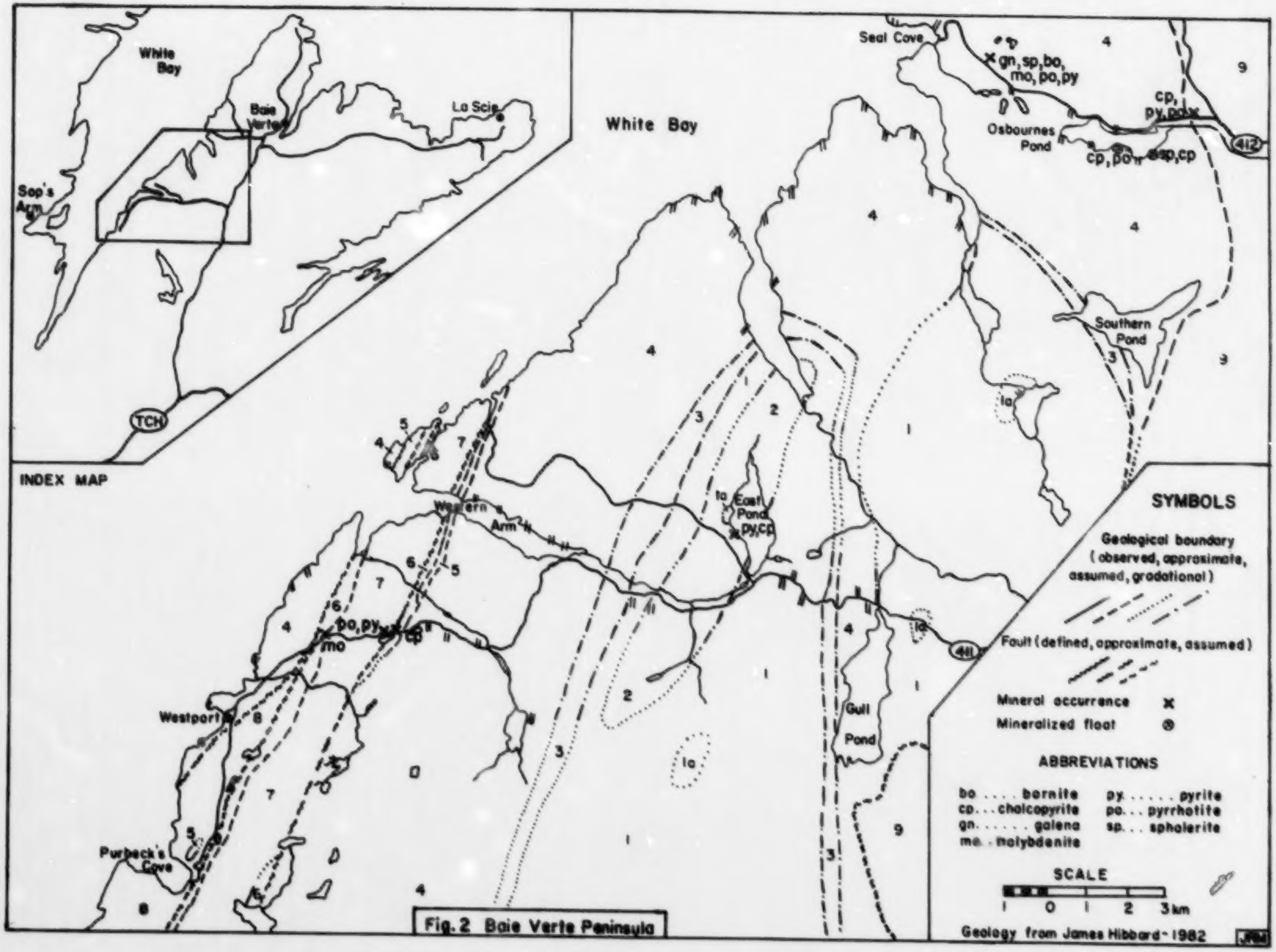
INDEX MAP
White Bay
Baie Verte
La Scie
Sop's Arm
TCH
White Bay
Seal Cove
× gn, sp, bo, mo, po, py
Osbournes Pond
cp, py, po ×
cp, po
sp, cp
412
Southern Pond
East Pond
py, cp
Western Arm
Westport
Purbeck's Cove
po, py
mo
cp
Gull Pond
411
1
1a
2
3
4
5
6
7
8
9
SYMBOLS
Geological boundary (observed, approximate, assumed, gradational)
Fault (defined, approximate, assumed)
Mineral occurrence ×
Mineralized float ⊗
ABBREVIATIONS
bo.... bornite
cp... chalcopyrite
gn...... galena
mo.. molybdenite
py...... pyrite
po... pyrrhotite
sp... sphalerite
SCALE
1 0 1 2 3 km
Geology from James Hibbard - 1982

Fig. 2 Baie Verte Peninsula

fluids favorable to ore deposition. Clearly, the results indicate a favorable potential for the discovery of clastic-hosted base metal sulfide deposits in Newfoundland.

Acknowledgements

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P.L. Dean

J.R. Meyer

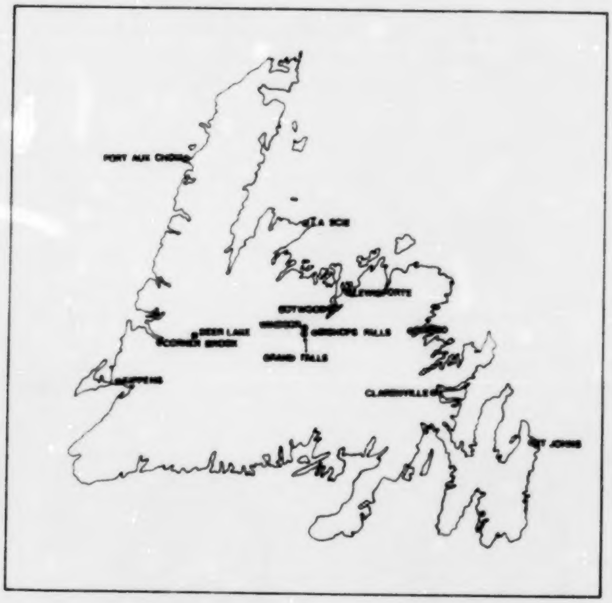
DETAILED AGGREGATE ASSESSMENT PROJECT, INSULAR NEWFOUNDLAND

by

F.T. Kirby
Environmental Geology Section

Introduction

This was the second year (Kirby, 1983) of the Detailed Aggregate Resources Mapping in Insular Newfoundland. Before the start of this project in 1982, detailed assessments of some areas were carried out under the Inventory of Aggregate Resources Program. These areas included Butts Pond (1979), Sandy Brook - Grand Falls (1979), and Gros Morne National Park (1981); a start had been made on the St. John's Urban Region Plan Area (1981). During the 1982 field program, aggregate resource assessments were done in 13 municipal planning areas throughout insular Newfoundland (Map I).



Map I: *Detailed aggregate resources project; insular Newfoundland field areas, 1982.*

Objectives of Program

The main aim of the project is to identify areas of quality aggregate resources within municipal or other areas where the implementation of land use zoning might sterilize (remove from future production) areas of aggregate resources. The process involves locating and sampling in detail any aggregate reserves within the proposed development or plan areas. In areas lacking quality aggregates (i.e. gravels and sands), alternative sources such as silt/clay-free till and/or suitable bedrock are assessed for current and future needs. The inclusion of the aggregate resources inextraction areas within specific planning proposals (e.g. municipal plans) is suggested to ensure that the aggregates can be preserved to meet the future aggregate demand in these areas. This likewise ensures that the local domestic and commercial aggregate consumer has access to material at a reasonable cost.

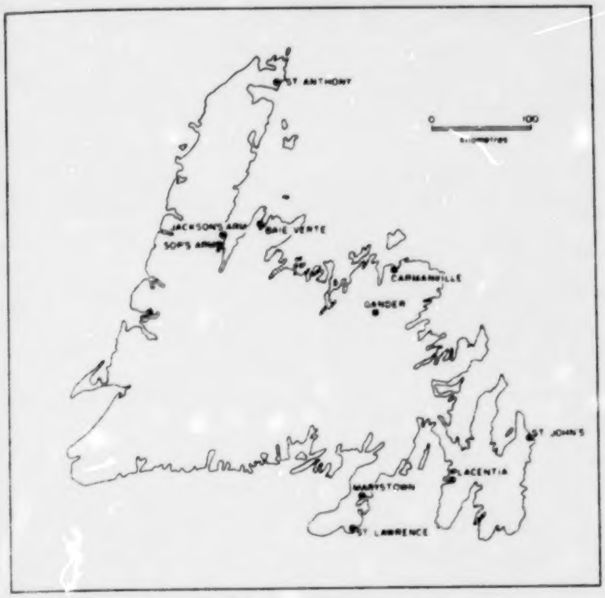
Field Program, 1983

Field work was started in early June and ended in late October. Municipal planning areas included St. Anthony, Sops Arm, Jacksons Arm, Baie Verte, Gander, Carmanville, Marystown and St. Lawrence. Backhoe test pitting conducted in the St. John's Urban Region Planning area (Map II), in October completed field work on that plan area.

Preliminary field work was conducted by vehicle along all roads and trails in the study areas. Where vehicular access was limited, foot traverses were conducted. Information obtained from this preliminary field work, combined with information obtained from surficial and aggregate resources maps and particle size data produced by the Inventory of Aggregate Resources Project, enabled us to identify the areas with the most aggregate potential.

In areas where it was determined that suitable aggregate reserves exist, foot traverses were conducted to determine accessibility and the general nature of the deposit. Where forest cover and general topography permitted, backhoe test pitting was used to determine more accurately the depth and quality of the deposit. In less accessible areas, shallow hand-dug pits were used to obtain samples of the underlying aggregate materials.

Project funded by the Newfoundland Department of Mines and Energy.



Map II: *Detailed aggregate resources project, insular Newfoundland field areas, 1983.*

Approximately 450 aggregate and rock samples were collected in 1983. All aggregate samples collected were field-sieved using a bank of four 30 cm diameter brass sieves (63 mm, 31.5 mm, 16 mm, 8 mm). Sample fractions retained on each sieve were weighed and the weights recorded. A 500 g split of the sample passing the 8 mm sieve was retained for further laboratory sieve analysis. A split of the -32 mm +16 mm pebble fraction was retained for lithologic and petrographic number analyses.

Preliminary field mapping in each area was conducted at 1:50,000 scale to supplement previous aggregate resource data (Kirby et al., 1983). Detailed sampling and backhoe test pitting were normally conducted at 1:12,500 scale using orthophotos or enlargements of 1:50,000 scale topographic mapping. Where available, larger scale municipal plans (supplied by the Department of Municipal Affairs) were used.

Fall/Winter Program, 1983

During the late fall of 1983, a series of 1:50,000 and 1:12,500 scale maps outlining the areas of aggregate potential for each area studied will be compiled. These maps will be forwarded to the Department of Municipal Affairs for inclusion into their Municipal Plans.

During the winter of 1983-84, maps and sample analyses with accompanying reports will be compiled for open file release.

Plans

Detailed aggregate resource sampling and mapping within municipal planning areas and any major development areas will be continued until all areas have been surveyed.

There are more than three hundred municipalities in the province, over fifty of which have municipal plans in effect. The provincial Department of Municipal Affairs is completing municipal plans for many of the remaining areas as quickly as possible. To date, 26 municipal planning areas have been included in the survey.

Acknowledgements

The author thanks Paul Legrow for his capable assistance in the field and Christine Spurrell for her work in the laboratory.

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F.T. Kirby

AGGREGATE RESOURCES INVENTORY SYSTEM

by

J. Atkinson
Environmental Geology Section

The Environmental Geology Section has been collecting aggregate resource data since 1975. To this time, approximately 10,000 samples have been collected. The database management system selected for the manipulation of the data is the Scientific Information Retrieval (SIR) system. The end product is the Aggregate Resources Inventory System, an interactive database designed for the storage and retrieval of aggregate and surficial geology data generated. This report is a brief description of the system as well as the type of data the system holds.

The system consists of a series of programs which permit the user to:

(1) edit raw data collected by the geologists

(2) correct any data which was coded incorrectly or omitted

(3) produce cumulative curve plots of gravel, sand, silt-clay percentages for individual samples

(4) produce various reports on paper or microfiche, e.g. master-file report, lithological analysis report, particle-size-analysis report

(5) add, change or delete any data in the database

(6) unload the database from disk to tape

(7) reload the database from tape to disk

(8) check the integrity of the database for any changes since the last time it was accessed

The data in the database can be roughly divided into two categories, information pertinent to a specific sample site or location, and information related to individual samples taken at the site. Of the sixteen record types defined for the database, records 1-6 hold site information and records 7-16 hold information related to a particular sample. This set-up gives the database a hierarchical structure, i.e. each site record has many sample records associated with it.

The record types which pertain to a specific site hold such information as:

(1) general location of the site

(2) the landform associated with the site

(3) any ice movement indicators found at the site

(4) a list of any photographs taken

(5) general comments by a geologist concerning the site

The records which hold sample information report on:

(1) a field description of the sample

(2) field sieve analysis data

(3) pebble analysis data

(4) lithology data from the pebbles in the sample

(5) laboratory sieve analysis data

(6) general comments relating to the sample

Data are continually being added to the database, with emphasis being placed on data collected in 1980-1982. As of August 31, 1983, the database held information on approximately 4000 sites, with a total of approximately 20,000 records on file. These data were collected primarily from Insular Newfoundland; Labrador data were collected in 1983 and before 1980 and are not in the system. The 1983 data will be input as soon as possible.

J. Atkinson

Project financed by the Newfoundland Department of Mines and Energy.

THE DEVELOPMENT OF MICROCOMPUTER PROGRAMS FOR USE BY GEOSCIENTISTS IN THE MINERAL DEVELOPMENT DIVISION

by

H. Missan
Computer Unit

The Mineral Development Division is responsible for collecting, archiving and processing large quantities of geological, geochemical, mineral deposit, and surficial geological data for evaluation of the mineral resource potential of Newfoundland and Labrador. Because of the increase in volume and complexity of these data, sophisticated computer programs are being used in their analysis. All these programs (and data) are presently residing on the AMDAHL V/7 mainframe computer of the Newfoundland and Labrador Computer Services (NLCS). To use the programs, one has to be familiar with operating system procedures of the AMDAHL computer, which in themselves are complex. Hence, as a result, very few geoscientists are able to use these programs to analyze their data themselves.

To overcome this shortcoming, the Computer Unit has decided to shift the emphasis towards development of 'user-friendly' programs on in-house micro-computers. The objective is to give research geoscientists the tools to store, analyze and retrieve their own data without having to become proficient in computer systems or computer languages. The Computer Unit has two microcomputers:

(1) Tektronix 4054 Graphic System with a plotter.

(2) Texas Instrument Professional Computer with a 132 column printer.

Development Work on the Tektronix Graphic System

The Tektronix Graphic System consists of:

a) 19" high resolution Graphics Screen;

b) 64K (RAM) memory;

c) a 300K tape drive cartridge system for storing programs and data;

d) a hard copy unit for photocopying the screen (11" x 8");

e) a 2-pen color plotter (22" x 17") for plotting camera-ready diagrams on mylar.

The Tektronix system uses the BASIC language so only programs written in BASIC can be used on it, which is a drawback. It is connected to the AMDAHL computer at NLCS, enabling the transfer of data between the two systems.

The most widely used program on the TEKTRONIX 4054 is MICRO-GRASP(*). This program provides for the storage, transformation, selection and display of data in tabular form. The user controls the execution of MICRO-GRASP by entering a series of "commands". There are 12 commands which can be used. These commands allow users to enter new data records, establish selection criteria, calculate summary statistics, display selected data values, perform arithmetic operations, review the status of the system, and terminate the session. In addition, the user can do graphics work such as plotting Harker variation diagrams and ternary diagrams. These can be either drawn on the screen or plotted on the plotter.

Proposed Development Work on the Texas Instrument Professional Computer

The Computer Unit has recently acquired a 16-bit Texas Instrument Professional Computer System. The system consists of:

a) a 13" color graphics screen;

b) 320K RAM memory;

c) a 320K disk drive for storing programs and data;

d) a 5 megabyte Winchester drive for storing programs and data;

e) an operating system which allows the user to run programs written in FORTRAN and BASIC languages;

f) a 132 column printer.

This computer is also connected to the AMDAHL for the purpose of data transfer. Work is underway to implement MICRO-GRASP on this system, too. In addition, the following programs are being evaluated for implementation:

(a) CIPW(*)

This program computes the CIPW norm, which expresses the chemical composition of a rock in terms of standard mineral molecules. In addition to CIPW norm, the Thornton & Tuttle Differentiation Index, Barth's cations,and Niggli values are computed.

(b) MINRL NORM(*)

This program is used for deriving formulas from chemical analyses of minerals using the anion-based, hydrogen-equivalent method. Input data consist of weight percentage of oxides or halogens and, if desired, the density and cell volume of the mineral. From these data, the computer calculates the number of ions per molecular formula, normalized values of ions, grain-formula weight, calculated density, and/or calculated cell volume. The program is designed to provide a maximum flexibility of output with a minimum of input data. It provides a standardized basis of comparison of mineral norms, and permits systematic searches for integral anions per formula or formulas per unit cell, if these parameters are unknown.

(c) MICROSTAT

Microstat is a commercial statistical program developed by ECOSOFT. It is a library of statistical programs that perform the most common statistical tests and procedures. It was developed for "real life" applications using fairly large data sets. Computation algorithms were selected for accuracy and speed.

More programs will be added to the system depending on the users' needs.

Conclusions

The MICRO-GRASP system on the Tektronix has been used by some geologists for manipulating and analyzing data. Experience has shown that, after a training period of about one hour, a geologist can start using the system to obtain the required information from the data base.

The development of user-friendly programs on the microcomputer will provide another tool for the geologists in their scientific work. A geologist will be able to command a computer system to work for and with him, doing the tedious parts of the work and presenting him with condensed views of his data, allowing him to visualize the information in different ways and encourage a dialog between the thinking scientist and the functional machine.

H. Missan

(*) These programs were developed by: Roger Bowen of the United States Geological Survey

GEOSCAN - THE NATIONAL DATABASE FOR GEOLOGICAL INFORMATION: THE NEWFOUNDLAND CONTRIBUTION

by

Catherine Patey
Publications and Information Section

GEOSCAN is a computerized bibliographic database of Canadian-produced and/or Canada-related geoscience documents.

The Newfoundland Department of Mines and Energy is one of the ten agencies which index documents for input into this database. Our 'geofiles' and mineral inventory cards are the sources of our indexed documents. Other agencies, e.g. the Geological Survey of Canada and the Earth Physics Branch of the Canada Department of Energy, Mines and Resources, also produce and index documents that concern this province.

In 1982, the National GEOSCAN Centre, which manages GEOSCAN, implimented a new software system, called MINISIS, to input and retrieve the bibliographic data more effectively. Since then, the old and the new systems have been operating concurrently.

The old documents are available in the GEOSCAN Newfoundland and Labrador indexes, current to February 1982, the date of the last update on the old system. These indexes are available from the Publications and Information Section. (See page 27 of the Publications List.)

As well as these products, all of the 67,000 GEOSCAN records from across Canada including those concerning this province are available through on-line computer searches at the Geological Survey of Canada Library in Ottawa and, locally, at our Publications and Information Section. Searches are performed on a cost-recovery basis with a minimal charge of $10.00 per search topic. A moderate size search (100-200 titles) costs between $15 and $45.

In the implementation of the new system, all the old documents were converted to a new format. For example, different types of keywords were moved into different fields - map types, illustrations, geological terms. Although most of the records did convert, they did not convert cleanly and completely. For example, reports may be missing a title or authors and terms may have been assigned to the wrong fields. Until the National GEOSCAN Centre has completed its modifications of these converted documents, individual agencies cannot do the more detailed modifications such as changing confidential status. In the meantime, we welcome suggestions for improvements and appreciate being notified of any errors or discrepancies that you may discover in the earlier indexes. This would aid us in making detailed modifications of the documents.

All new documents are input directly on to the new system and are immediately retrievable on-line. To date, only indexed documents from assessment files have been keyed into the system, although other types of documents, in particular government publications, have been coded.

Besides indexing and keying new documents, new coding sheets are being produced, the authority files or thesauri used in coding are being enlarged, and the terms used are being more clearly defined.

When the new system is fully in place, GEOSCAN should be a much more valuable tool in our search for new mineral resources.

For further information on GEOSCAN, please contact Catherine Patey (709) 737-3159. We appreciate your comments and suggestions.

Catherine Patey

GEOFILES - MICROFICHE PROJECT

by

N.L. Mercer
Publications and Information Section

The Mineral Development Division maintains a geological and mineral resource assessment file system commonly referred to as the "geofiles". The geofiles presently consist of approximately 8,500 geological and geochemical reports, maps, journal articles and mineral assessment files, making them the largest and most comprehensive single collection of geoscience documents about Newfoundland and Labrador.

As a result of the high level of mineral exploration activity during the late 1970's - early 1980's throughout the province, the amount of new data submitted increased substantially. New information is now available on many of the old and also numerous new mineral occurrences in the province. Much more is now known about the geology and mineral potential of various regions both on the island and in Labrador.

The Mineral Development Division has also conducted a large number of field projects over the past few years. This has resulted in the publication of many new geological reports, maps and open files as well as the results of numerous geochemical surveys and surficial and aggregate resource studies.

Mining and exploration companies, prospectors, geotechnical and consultant firms, government agencies, universities, libraries and the general public are continually making use of the geofiles and requesting information from them. Requests have nearly tripled in the past few years.

During the past four years, the Publications and Information Section has been putting all the geofiles on microfiche. This provides a much more efficient system of maintaining the geofiles. Requests for information are processed more rapidly and easily, with relatively inexpensive charges for microfiche.

The microfiche project involves daily filming of batches of files. The files are cross-checked before filming for quality, content and reproducibility. Two microfiche originals are made and cataloged for each file. Filing follows the standard N.T.S. system. Duplicates can be copied from the original fiche upon demand. One set of fiche originals is stored offsite at the Torbay Core Library for security and protection from fire.

Microfiche sets of geofiles covering all 1:250,000 N.T.S. blocks in insular Newfoundland are available at a total cost of $1,122. Response to this project so far has been excellent, with several companies purchasing all available microfiche sets.

In 1983, some work was done on the Newfoundland General Series of geofiles. Microfiche duplicates are available for 226 (of about 1350) geofiles from this series.

During 1983, we also started placing the mineral occurrence reports on microfiche and making them available. Presently, mineral occurrence reports for N.T.S. 2E, 12B and 12H in Newfoundland and N.T.S. 13K and 14C in Labrador are available. Further releases will be made as staff in the Mineral Deposits Section complete new N.T.S. areas.

For information, please contact Norman Mercer (709) 737-3159. We look forward to your comments and suggestions.

Acknowledgements

Rick Soper and Doreen Mahon are thanked for their work on the microfiche project.

The Department of Mines and Energy also acknowledges the continued participation and cooperation of Ches Hapgood and staff of the Micrographics Section, Newfoundland Department of Public Works and Services, especially in filming and duplicating the geofiles.

N.L. Mercer

Project funded by the Newfoundland Department of Mines and Energy.

MINERAL OCCURRENCE DATA SYSTEM

by

C.F. O'Driscoll
Mineral Deposits Section

Introduction

The Mineral Occurrence Data System is designed to offer an efficient information service on all mineral occurrences in Newfoundland and Labrador. It is a two-part project comprising a Mineral Inventory File done on a word processor and a computerized Mineral Index.

Mineral Inventory File

The Mineral Inventory File is part of the National Mineral Inventory and consists of mineral occurrence descriptions which summarize all the available information on known mineral occurrences in the province. A description may be prepared for any type of occurrence from an indication to a producing mine.

To date, information on all mineral occurrences for the island of Newfoundland has been compiled (Figure 1). During 1983, the mineral occurrences for areas 12A, 11O, 11P, 1L and 1M were completed. In Labrador (Figure 2), areas 23J and 23I have also been completed. These descriptions are now being edited and will be available within the next few months. In addition, areas done previously have been updated and the revised descriptions are now available.

Mineral inventory descriptions and 1:50,000 scale location maps are presently being microfiched. Areas which have been completed and are now available are 2E, 12B and 12H on the island, and 13K and 14C in Labrador.

After descriptions are completed for an NTS area, the occurrences are plotted on maps with updated geological bases and then published. Mineral occurrence maps (1:250,000) have been published for NTS areas 12B (Stephenville), 2E (Botwood), and 14C (Nain). In addition, during 1983, maps for the following areas were published: 13K (Snegamook Lake, 1:250,000), 13K/5 (Wuchusk Lake, 1:50,000), parts of 13J and 13O (Rigolet and Makkovik, 1:100,000). Maps in the following areas have been prepared and will be published within the next year: 1K-1N (Avalon Peninsula), 2C (Bonavista), 2D (Gander Lake), 2F (Wesleyville), 12G (Bay of Islands), 12H (Sandy Lake), 12I (Port Saunders), 12P-2M (Blanc Sablon - St. Anthony) and 13N (Hopedale).

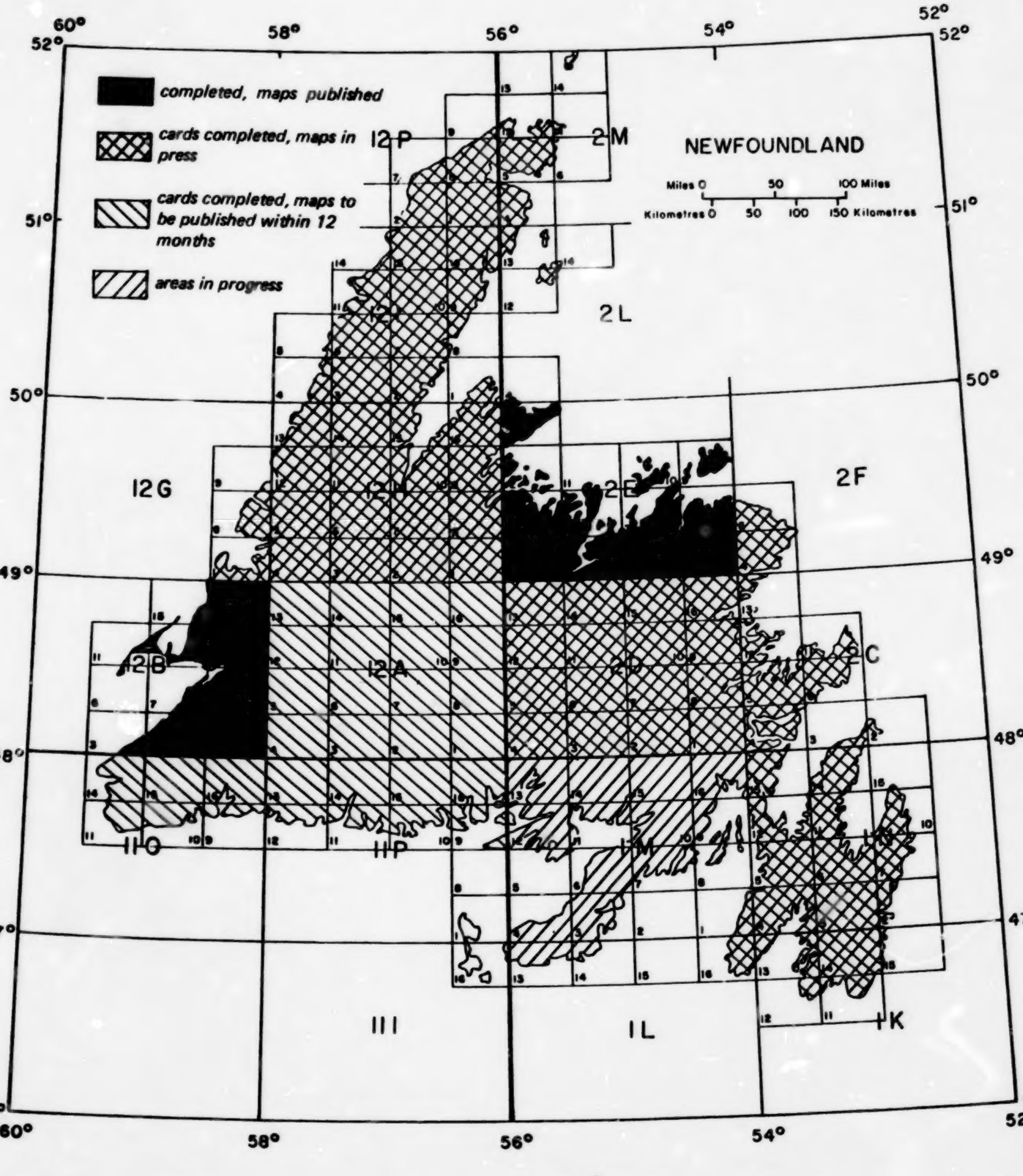
Computerized Mineral Index

The computerized Mineral Index is organized so that a wide variety of complex retrievals can be made which would be virtually impossible with a manual system. The computerized index contains information selectively extracted from the Mineral Inventory File.

All occurrences compiled before 1983 have been coded and input into the computer. Those occurrences compiled in 1983 are now being coded and will be input within the next year.

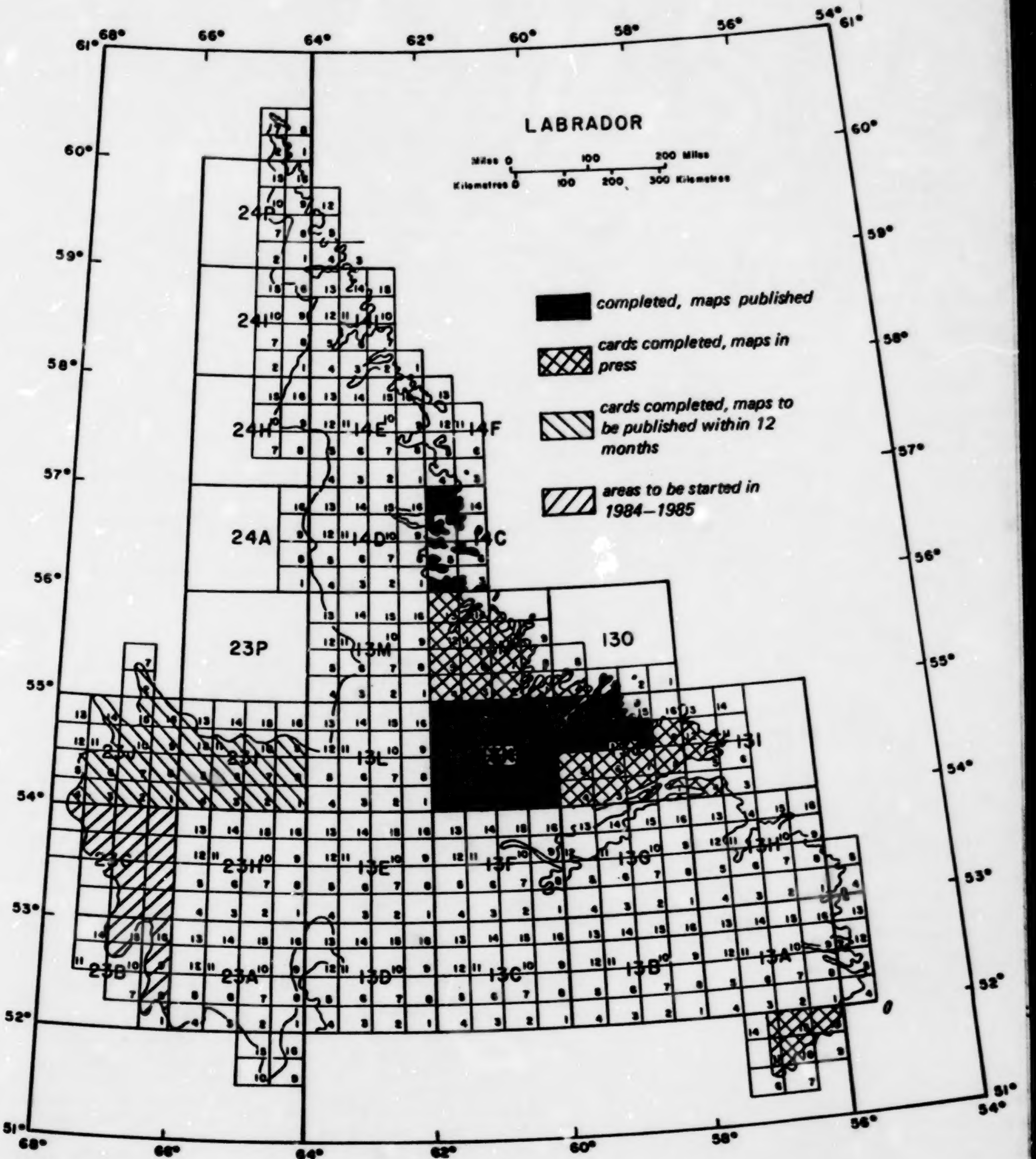
C.F. O'Driscoll

Project financed by the Newfoundland Department of Mines and Energy.



completed, maps published
cards completed, maps in press
cards completed, maps to be published within 12 months
areas in progress
NEWFOUNDLAND
Miles 0 50 100 Miles
Kilometres 0 50 100 150 Kilometres
60°
58°
56°
54°
52°
51°
50°
49°
48°
47°
46°
12 P
2M
2L
12G
2E
2F
12B
12A
2D
2C
11O
11P
1M
11I
1L
1K

Figure 1: *Index map for Mineral Occurrence Data System project, insular Newfoundland.*


LABRADOR
Miles 0 100 200 Miles
Kilometres 0 100 200 300 Kilometres
completed, maps published
cards completed, maps in press
cards completed, maps to be published within 12 months
areas to be started in 1984–1985
24P
24I
24H
24A
23P
14E
14F
14D
14C
13M
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13I
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23I
23G
23H
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13F
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13H
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64°
62°
60°
58°
56°
54°
61°
60°
59°
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57°
56°
55°
54°
53°
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51°

Figure 2: *Index map for Mineral Occurrence Data System project, Labrador.*

CORE STORAGE PROGRAM, 1983

by

A. Harris and S. Cochrane
Publications and Information Section

During 1979, the Newfoundland Department of Mines and Energy started a drill core collection and storage program. The objective is to provide well maintained and representative collections of drill core from as many drilling programs as possible for the future use of the mineral exploration industry, government geoscientists, university geoscientists and other geotechnical people.

Drill Core Collection

During the 1983 field season, drill core collection from abandoned drill sites was completed in Insular Newfoundland and continued in Labrador. In Insular Newfoundland, 19,899 m of core were collected from eight projects and 9,129 m of core were moved from a temporary storage location at Springdale to our core library in Pasadena. Figure 1 shows the locations of all sites from which core has been collected in Insular Newfoundland and Table 1 provides a list of the collected core.

In Labrador, 1,252 m of core were collected from three sites during 1983. This completed collection from abandoned drilling sites in the Central Mineral Belt of Labrador. Figure 2 shows the locations of all sites from which core has been collected and Table 2 provides a summary of the collected core.

New acquisitions of drill core from Labrador and Insular Newfoundland during 1983 total 21,151 m. To date, the core storage program has collected 141,457 m of drill core.

Some drill core is presently being stored on a confidential, temporary basis. Requests for confidential storage are treated on an individual basis. Conditions and terms of confidential storage are tied to land status and are similar to the terms and conditions of confidentiality which apply to assessment reports.

Section 64 of the Mineral Regulations has been amended to encompass the removal of drill core from the province. The Mineral Regulations regarding drill core now read as shown in Appendix I.

Drill Core Libraries

The Department of Mines and Energy operates three drill core libraries, located in St. John's, Pasadena and Goose Bay (Figure 3).

The St. John's library is staffed on a full-time basis, except during the field season. It has a capacity of 60,000 m of drill core. Approximately 12,000 m of drill core have been cataloged and placed on the rack system to date. Most of this core is from eastern Newfoundland, from the St. Lawrence area and the "silica survey" drilling conducted by the government during the 1960's. Drill core logs and location maps have been prepared for cataloged core. The St. John's library also contains rock cutting equipment, core splitters, a stereomicroscope, a magnetic susceptibility meter, a resistivity meter, an ultraviolet light and a McPhar TV-1 scintillometer. These facilities and equipment are available for use on approved projects by exploration geologists, university researchers, the staff of the Department of Mines and Energy and other interested persons.

The Pasadena core library is also staffed on a full-time basis. This library has equipment and facilities similar to the St. John's library and has a capacity of 200,000 m of core. It has a ventilated room for storing radioactive core and a humidity-controlled room for storing salt core. There are approximately 114,000 m of core presently stored in the Pasadena library, collected from drilling sites west of Gander.

The Goose Bay core library is not staffed on a full-time basis. It has a capacity of 60,000 m of core, with room for expansion. Approximately 8,600 m of core have been cataloged and placed on the rack system to date.

Plans

Plans include cataloging and indexing all drill core collected to date and continuing collection programs, with emphasis on St. John's and Pasadena during the offseason. There is space available in all three libraries for confidential storage. We encourage explorationists to use our facilities for core storage and related research.

An index of all core in the three libraries is available.

Table 1: *Summary of core collected to date - insular Newfoundland*

No.	Company	Year	Property	# of Holes	Total Metres	Storage Location
1	Advocate	1967	Rambler	2	1,193.0	P
2	Amax	1976	Fischells Area	2	1,420.3	P
3	Amoco	1978	Burnt Pond	4	609.6	P
4	Beth Canada	1978	Springer's Hill	10	911.7	P
5	Boylen-Cerro		Colchester	18	1,379.2	P
6	Canadian Ref.	1970	Aguathuna	13	850.1	P
7	Chevron	1979	Eddies Cove	11	481.6	P
8	Cominco-Hansa	1973(?)	Bobby's Pond	5	431.6	P
9	Hooker Chemical	1968	Fischells	1	173.4	SJ
10	HBOG	1978	Gt. Rattling Bk.	11	818.6	P
11	HBOG	1978	Reid Lot 223	5	306.3	P
12	HBOG	1978	Reid Lot 225	2	117.0	P
13	HBOG	1978	Top Pond	1	47.1	P
14	Internat. Mogul	1974	Campbellton Area	15	1,394.5	P
15	Internat. Mogul	1975	Gander Area	12	708.7	P
16	Minorex	1978	Atlantic Lake	6	439.5	P
17	Nfld. Mines Br.		Port au Port	?	811.5	P
18	Noranda	1972	Point Leamington	3	265.8	P
19	Noranda	1973	Gullbridge	1	54.9	P
20	Noranda	1975	Leonard's Lake	3	388.6	P
21	Noranda	1975-78	Tally Pond	2	489.2	P
22	Noranda	1978	Burnt Pond	2	165.0	P
08	Noranda	1978	Bobby's Pond	4	320.6	P
23	Shell Can. Res.	1975-76	Main Brook Area	32	1,859.3	P
24	Texas Gulf	1975	Seal Bay	8	1,104.9	P
19	Gullbridge Mines	?	Gullbridge	213	12,473.9	P
25	Consol. Morr.	1976	Lake Bond	2	419.1	P
26	L.M. & E.	?	Lake Ambrose	6	647.7	SJ
27	Kerr Addison	1974-75	Victoria Area	5	655.3	P
28	Shawmont	1977-78	Hinds Brook	28	822.9	P
29	Advocate	?	Priests Showing	8	774.6	P
30	Advocate	?	Nippers Harbour	7	946.1	P
31	Advocate	1976	West Pond	3	144.7	P
32	Advocate	1975	Flatwater Pond	11	907.6	P
33	ALCAN	?	St. Lawrence	?	8,153.4	SJ
34	D.S. Robertson	?	Mt. Margaret Area	?	4,463.8	SJ
35	D.S. Robertson	?	Lawn Area	?		SJ
36	Noranda	?	Round Pond Area	?	?	P
37	RIOCANEX	1976	Cold Spring Pond	1	30.0	SJ
38	Falconbridge		Strickland Property	?	4,427.2	P
39	Falconbridge	1981	Burgeo Road	16	1,059.2	P
40	Long Lac Min.	1968	Strickland Property	18	975.3	P
41	Minorex	1978-80	Deer Lake	25	1,993.3	P
42	U.S. Borax	1979	Hidden Pond	11	237.6	P
43	Nfld. Mines Branch	1960's	Fortune (Silica)	3	199.9	SJ
44	Nfld. Mines Branch	1960's	Long Harbour (Silica)	6	232.5	SJ
45	Nfld. Mines Branch	1960's	Argentia (Silica)	11	731.6	SJ
46	Nfld. Mines Branch	1960's	Thornlea (Silica)	6	230.9	SJ
47	Nfld. Mines Branch	1960's	Bellevue (Silica)	7	187.1	SJ
48	Nfld. Mines Branch	1960's	Long Cove (Silica)	4	164.1	SJ
49	Nfld. Mines Branch	1960's	Grey River (Silica)	6	256.2	SJ
50	Nfld. Mines Branch	1960's	Bonne Bay (Silica)	4	197.2	SJ
51	U.S. Borax	1981	Daniels Harbour	2	804.6	P
52	Minorex	1981	Silverdale	7	203.6	P
53	Minorex	1979-80	Deer Lake	?	109.7	P
54+	Westfield Minerals	1978-81	Deer Lake	130	8,314.9	P
55+	Northgate Expl.	1979	Deer Lake	16	2,511.5	P
56	Riocanex	1978-81	Cape Ray	171	20,461.0	P
57	Essex	1981	Watts Bight	4	609.6	P
58	Shell Can. Res.	1980	Codroy Valley	6	890.0	P
59+	Flintkote	1979-80	Flat Bay	?	3,214.0	P
60+	Newmont	1981	Tilt Cove	6	864.1	P

Table 1: *(Cont'd)*

No.	Company	Year	Property	# of Holes	Total Metres	Storage Location
61+	Rambler Mines	?	Ming Mine	64	19,150.0	P
62	BRINEX	?	Whaleshack	235	12,226.0	P
63	Riocanex	1976	Great Burnt Lake	9	1,463.0	P
64	St. Joe Can.	1982	Big Pond	9	707.0	P
65	Billiton	1981	Ghost Pond	3	668.0	P
66+	Esso Minerals	1982	Ackley Granite	5	280.0	SJ
67	HBOG	1980	Gander Lake South	7	296.1	P
68	HBOG	1980	New Bay Pond	6	356.8	P
				Total	131,203.3	

Key P - Pasadena, SJ - St. John's, + - Confidential

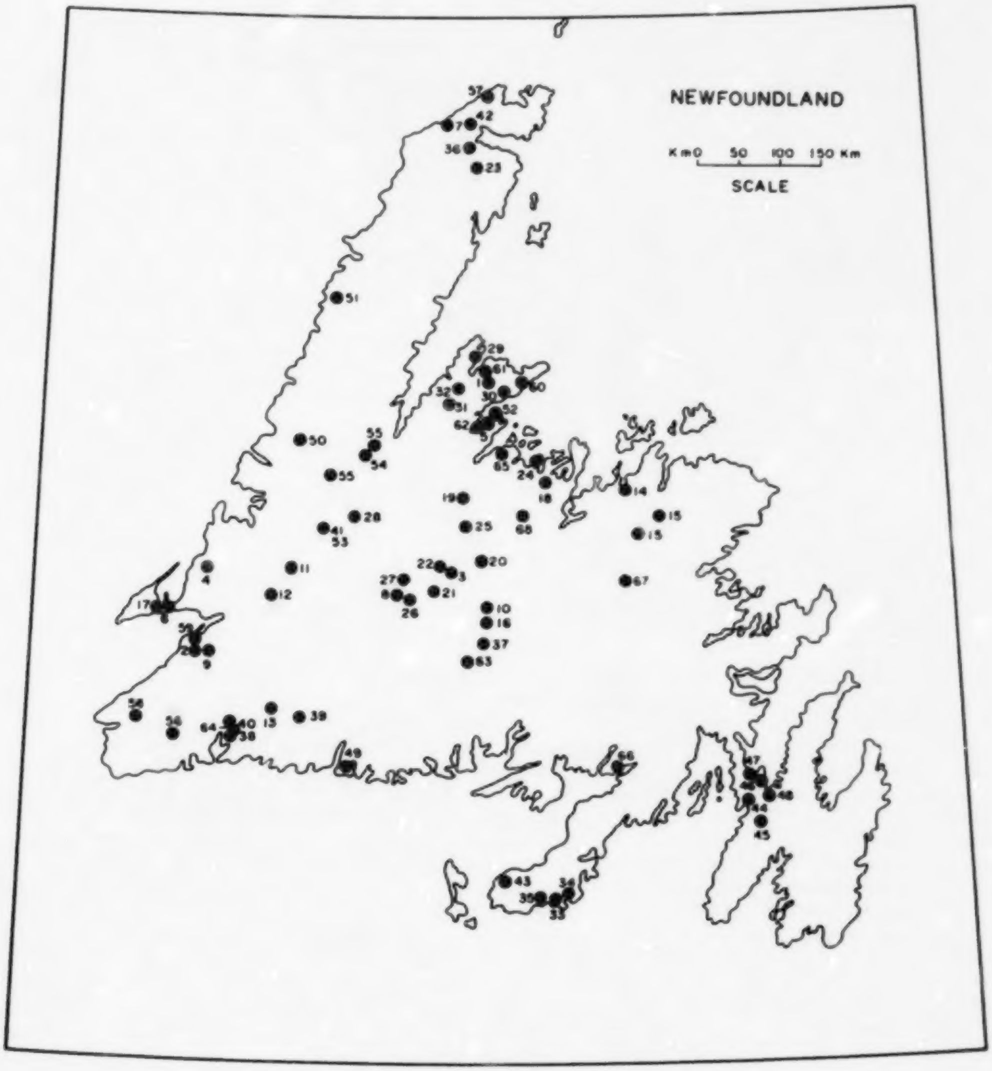
NEWFOUNDLAND
Km 0 50 100 150 Km
SCALE
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Figure 1: *Core collection sites, insular Newfoundland.*

TABLE 2: SUMMARY OF CORE COLLECTED TO DATE - LABRADOR

No.	Company	Year	Property	# of Holes	Total Metres	Storage Location
1	American Metal Co.	1954	Green Pond	3	16.7	GB
2	Brinex	1972	Seal Lake	19	1,333.5	GB
3	Canadian Nickel Co.	1978-80	Moran Lake	30	2,103.1	GB
4	Mokta Can. Ltd.	1965	Moran Lake	8	220.9	GB
5	Northgate Explor. Ltd.	1980	Lake Melville	8	652.2	GB
6	Placer Devel. Ltd.	1980-81	Banana Lake	11	655.3	GB
7	Riocanex	1961	Ten Mile Lake	4	197.5	P
8	Shell Can. Res.	1977-79	Moran Lake	61	3,822.2	GB
9	Shell Can. Res.	1977	Sylvia Lake	3	99.4	GB
10	Shell Can. Res.	1977	Madsen Lake	2	114.8	GB
11	Nfld. and Lab. Hydro	?	Gull Island		1,037.8	GB
				Total	10,253.4 m	

Key GB - Goose Bay, P - Pasadena

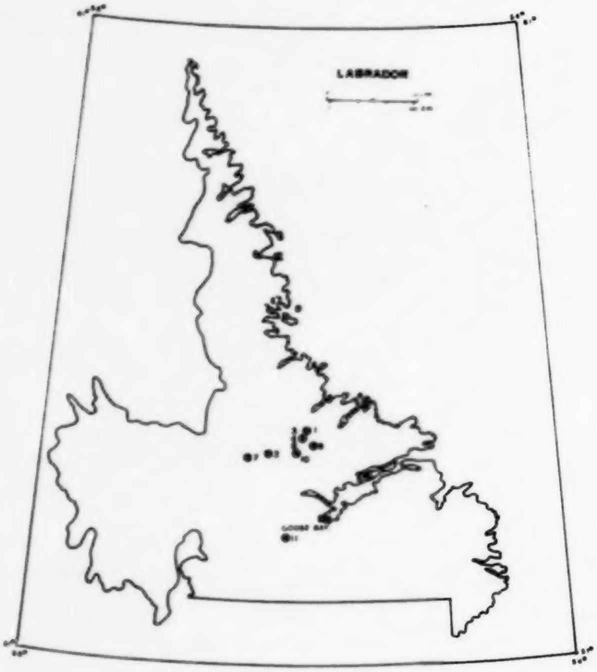
LABRADOR
GOOSE BAY

Figure 2: *Core collection sites, Labrador*

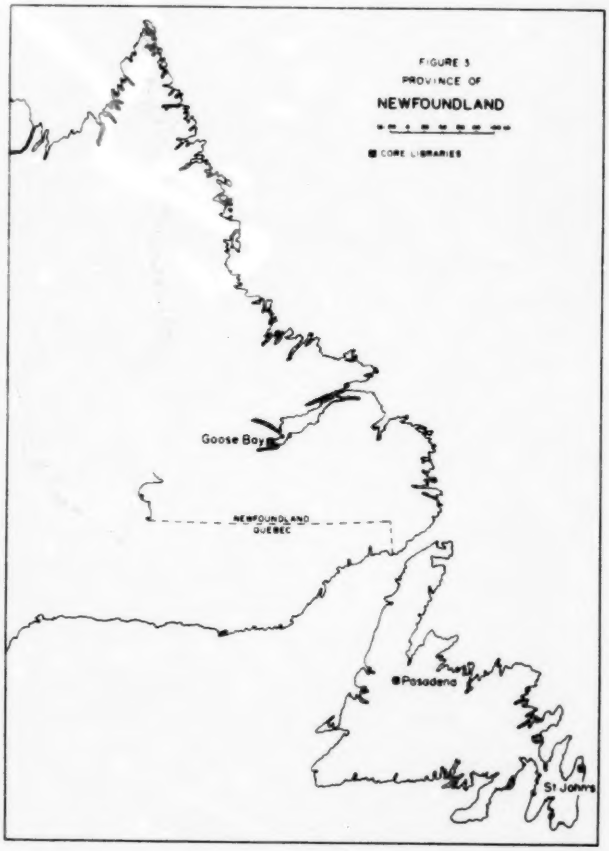
FIGURE 3
PROVINCE OF
NEWFOUNDLAND
CORE LIBRARIES
Goose Bay
NEWFOUNDLAND
QUEBEC
Pasadena
St Johns

Figure 3: *Core libraries in the province of Newfoundland and Labrador.*

APPENDIX I

MINERAL REGULATIONS RE: DRILL CORE

Preservation
of Diamond
Drill Core

64. No person, whether a holder of mineral rights issued under this Act or these Regulations or not, shall intentionally abandon, discard, dump, destroy or otherwise reduce the original technical value of any diamond drill core or rotary drill cuttings obtained for information purposes within the Province or remove same from the Province, except for those sections submitted for assaying, testing, microscopic, metallurgical and beneficiation studies, without the permission of the Minister.

Minister May
Allow Disposal
or Obtain Core
for Crown

65.--(1) All persons proposing to dispose of any diamond drill core in their possession or lodged with them for safekeeping, shall notify the Minister of their desire to do so and upon receipt of such notification the Minister

(a) shall provide such persons with permission in accordance with regulation 64 or

(b) may direct his authorized representative to take possession of such drill core for the Crown and take such other action as he may deem necessary.

(2) The actions directed by the Minister under paragraph (1) shall be undertaken at the expense of the Crown.

A. Harris

PROJECT REPORT OF THE GEOCHEMICAL LABORATORY FOR 1983

by

H.A. Wagenbauer
Geochemistry Section

Introduction

The analytical facilities of the laboratory remain as described in Wagenbauer et al. (1983). No new equipment has been acquired, but the staff level was reduced from eleven to six full-time employees. Consequently, it has not been possible to carry out any significant amount of methods development, and the range of analyses performed is unchanged from that described in Wagenbauer et al. (1983). The work done between September 1, 1982 and August 31, 1983 is summarized in Table 1. The total number of determinations is down by 16% from the previous year. This drop in output reflects the cuts in staff and budget.

References

Wagenbauer, H.A., Riley, C.A., and Dawe, G. 1983.
1983: Geochemical Laboratory. *In* Current Research. *Edited by* M.J. Murray, P.D. Saunders, W.D. Boyce, and R.V. Gibbons. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 83-1, pages 133-137.

Table 1: *Summary of output from the geochemical laboratory of the Mineral Development Division from Sept. 1, 1982 to August 31, 1983 compared with the previous 12 month period.*

Type of determination	Number of determinations 81/82	Number of determinations 82/83
Geochemical analysis of soil, till, and stream and lake sediments	40,641	42,188
Silicate analyses		
Trace elements	22,205	7,721
Major elements	28,967	28,993
Miscellaneous analyses		
(Assays, F, Sn, W, Ba, Sr, pH on a variety of sample types)	11,768	8,496
	103,581	87,398

H.A. Wagenbauer

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